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A. B. CONNER, DIRECTOR

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DIVISION OF CHEMISTRY

The Utilization of the Energy of Feed by Growing Chickens

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

T. O. WALTON, President

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The productive energy of a feed is its value for furnishing energy to an animal after all losses due to undigested material, metabolic products, and chemical changes of the material have been deducted. To say that a feed has a productive energy of 1.90 calories per gram means that the quantity of feed fed in addition to a ration already sufficient to maintain the chickens produced 1.90 calories in the fat and flesh gained for each gram of feed eaten over maintenance requirements. The exact estimation of the productive energy of a feed mixture has been determined as a basis with which to compare other feeds. Such comparisons will enable the productive energy of chicken feeds to be compared and determined.

Eleven experiments were made, involving 256 chicks. Analyses of the chicks and of the feed, digestion experiments with the feed, and other data were secured. Appreciable differences were found in both the weights and composition of some of the chicks fed the same feed for the same period of time, especially in the fat.

Maintenance requirements and productive energy calculated on the assumption that maintenance requirements vary according to the weight were found to vary less and to be more in accord with the previous results of other workers than those calculated on the assumption that the maintenance requirements vary according to the surface of the animal. The weight basis was therefore adopted. Individual chickens were found to differ both in their capacity to grow and to utilize feed so that maintenance requirements and productive energy values calculated from results from only 2 or 3 animals might not be correct. The use of the average weight by periods gave more concordant results than the average of the first and last weights.

Differences in environment, probably temperature, apparently caused differences in maintenance requirements for chickens on the same feed in different experiments. Maintenance requirements for chicks up to the age of about 28 and 42 days averaged, per day per kilogram live weight, 74.8 grams of total feed or 63.3 grams of effective organic constituents, or 48.7 grams of effective digestible nutrients, or 134 calories of productive energy or 200 calories of metabolizable energy.

The productive energy of the mixture averaged 1.79 calories per gram for the 10 experiments. The average productive energy of the effective organic constituents was 2.14 calories per gram, of the effective digestible nutrients 2.78 calories per gram, and 67.6 per cent of the metabolizable energy was productive energy. On an average, 74.2 per cent of the limited ration was used for maintenance, and 25.8 was stored as gain of protein and fat, while 42.1 per cent of the full feed ration was used for gain and 57.9 per cent for maintenance.

As an average of all the 11 experiments, 40.0% of the total protein eaten was stored by the chicks on full feed and 37.3% by those on limited feed. Of the digestible protein, 56.9% was stored by those on full feed and 52.9 by those on limited feed. The estimated productive value of the digestible protein averaged 71%. The average productive protein required for maintenance was 0.27 gm a day per 100 gm weight. Digestible protein required for maintenance averaged 0.37 gm per day per 100 gm of chicks, while total protein averaged 0.53 gm per day per 100 gm.

The experiments indicate that the protein of cereal feeds may have a higher biological value than it has been supposed to have.

TABLE OF CONTENTS

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THE UTILIZATION OF THE ENERGY OF FEED BY GROWING CHICKENS

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Exact methods for estimating the feeding values of feeds are needed for agricultural and commercial purposes. For agricultural purposes, they are needed in formulating standards for feeding animals, in deciding on rations to be used for feeding purposes, and in studies of the relative economy of various feeding stuffs. For commercial purposes, they are needed for aid in comparing the values of different lots of the same feed or different kinds of feeds with one another, for compounding commercial mixed feeds of the highest possible nutritive value at the lowest possible cost, and for comparing different kinds of commercial mixed feeds with one another.

A number of factors affect the value of a feed for animal production. These include the productive energy, the digestible protein, the constituents of the proteins, the various vitamins, chiefly A, D, and G, the minerals, especially lime and phosphoric acid, and in case of ruminants, the bulk, or volume, which helps to satisfy the appetite of the animal. The palatability also appears to be an important factor in inducing the animal to eat liberally of the mixture. The relative importance of these factors in the individual feed depends upon the kind of feed, the kind of animal, and the possible deficiency of the ration to be fed (16). For chickens, productive energy and digestible protein are the most important factors. For ruminants, the bulk or volume must also be considered. In judging the commercial value of unmixed feeds, other factors are considered which are presumably closely related to their feeding values, but perhaps sometimes assigned commercial significance out of proportion to their feeding value.

The only one of the factors mentioned above which will be discussed in this bulletin is the productive energy.

Productive Energy

It was formerly assumed that one pound of the digestible nutrients of one feed was as good as one pound of any other; thus, one pound of digestible nutrients in straw was assumed to be equal in feeding value to one pound of digestible nutrients in corn. It has been shown by Kellner (19), Armsby (1), Forbes and others, that this assumption is not correct. The energy losses consequent to digestion are much greater for each unit of digestible nutrients in straw than in corn, so that the net energy which the animal could secure from a pound of digestible material in corn is much greater than that which it could secure from a pound of digestible material in straw. The value of the digestible energy of one kind of feed might be different from that of another kind. Kellner (19) determined the quantities of fat which could be put on by a fattening steer, fed on a slightly fattening ration, by feeding additional quantities of protein, of fat, of starch, of crude fiber, and of sugar. Using the energy values so secured, he calculated the energy values of certain feeds from the digestible constituents and compared the calculated value with the actual quantity of fat put on a fattening steer by additions of these feeds to the ration. With cottonseed meal, peanut oil meal, palm oil meal, and linseed oil meal, he found that the experimental values were practically the same as those calculated, but with other feeds the values found by actual test were decidedly below that calculated. The net energy of wheat straw was about 20 per cent of that calculated on the assumption that digestible nutrients were equally valuable in all feeds, 63 per cent of that calculated for meadow hay, 69 per cent of that for clover hay, and 77 per cent of that for wheat bran. To put it another way, the assumption of equal value for digestible nutrients would give five times the actual value found by experiment with the wheat straw, nearly 1.5 times the actual value of meadow hay or clover hay, and 1.3 times the actual value of wheat bran.

After establishing the differences in the feeding value of the digestible nutrients of different classes of feeds, Kellner (19) devised methods for estimating and for calculating the productive energy of feeds, and proposed feeding standards based upon them. Kellner expressed productive energy in terms of starch. Armsby (1) also proposed standards and devised methods for estimating the productive energy of feeds, expressing the value as therms, a therm being 1,000 large calories. Forbes and associates have continued the work of Armsby. Kellner's system has been extensively used in Europe. However, the old system based on the incorrect assumption that one pound of digestible nutrients in one feed has the same value as one pound in any other feed is still used to a great extent in this country (26).

Some deficiencies in the ration may affect its utilization and so decrease the productive energy of feeds, as pointed out by Mitchell (21). Deficiencies which may result in a lower productive energy of the ration include sodium chloride for chicks and rats, according to Mitchell and Carman (25); protein for fattening sheep, according to Fraps (14); protein for dairy cows, according to Mollgard as cited by Mitchell (21); protein for rats, according to Mitchell (21); phosphorus for beef heifers, according to Kleiber, Goss, and Guilbert (20); iron and copper for rats, as found by Black et al., (4); sodium for rats, as found by Kahlenberg, Black, and Forbes (18); vitamin G for rats, as found by Braman et al., (5); and lime for sheep, as found by Jones and Stangel (17).

On the other hand, no effect on the productive energy of the ration was indicated by a deficiency of phosphorus in a ration for rats as reported by Forbes (9), or by a deficiency of vitamin A and vitamin B in a ration for rats as reported by Braman et al., (5).

Productive Energy of Chicken Feeds

The term productive energy, as used in this bulletin, is the same as the calories of energy gained by the chicken for one gram of the feed fed over the maintenance requirements. To say that a feed has a productive energy of 1.90 calories per gram means that one gram of this feed, fed in addition to the requirements for maintenance, has produced flesh or fat or other body material containing 1.90 calories.

Few data are available upon which to base the absolute productive energy values of chicken feeds. Mitchell and Haines (22) calculated from respiration experiments that the net energy of corn fed to hens was 2.83 calories per gram. Southgate (27) calculated a net energy of 1.8 calories per gram for 13 parts ground oats and 3 parts whole dried milk fed cockerels, on the basis of the gain of energy. Fraps (12) has estimated the productive energy of some chicken feeds and given factors to use in calculating the productive energy from the chemical composition, but the data on which these figures are based are very limited. Energy production coefficients for ruminants have been published by Fraps (11, 13, 14, 15).

Object of the Work

The exact determination of the productive energy of some standard samples or mixtures is needed to serve as a basis for the determination and correction of productive energy values of chicken feeds. When the productive energy of a few feeds or mixtures has been determined exactly, other feeds may be compared with them by appropriate methods and a system built up for comparing the productive energy of various chicken feeds. It is much simpler to compare a feed against a standard feed (alone or in a mixture) in order to determine its relative productive energy than to make a direct determination of the productive energy of such feed or mixture.

The work presented here has for its object the determination of the productive energy of a mixture of well-known feeds, so that similar mixtures could be used for purposes of comparison with other chicken feeds, and thereby furnish data to ascertain more exactly their productive energy values.

Method of Procedure

The plan of work is similar to that used by Mitchell (23) with pigs and by Southgate with chickens (27). The procedure was to feed two groups of chickens upon the same feed, one on full feed and the other on limited feed for the same period of time and under the same conditions, ascertain the gain of energy on the two levels of feeding, and from the results to calculate the productive energy of the mixture. The general procedure was as follows: Day-old chickens were placed upon the feed to be tested for a period of about a week. The chickens were then weighed and divided into four groups, three being approximately equal in weight. One group (usually 4) of representative chickens of average weight were killed for analysis. Another group was placed upon full feed, generally *ad libitum*, and a third group was placed on limited feed, the quantity fed being about half that fed those on full feed and the amount fed daily being based upon previous experience. A fourth group, consisting of the chicks left over after equalizing the other groups, was used for digestion experiments. The chickens were fed individually in battery brooders, each compartment being divided by screen wire to furnish two spaces each to contain one chicken. The chickens were weighed every week. The feed was weighed into fruit jars, and weighed quantities fed daily. At the end of the experiment, the weight of the feed remaining served as a check upon the total of the daily weights fed. At the end of the desired period of time, the chickens were killed and analyzed. Digestion experiments were made on the mixtures fed.

Several methods of preparing the chickens for analysis were tried. One method consisted in drying the entire chicken and grinding it through a Wiley mill. Any fat which came out was dissolved from the vessel in which the chicken was dried and weighed separately. The dried chicken was found to be so hygroscopic as to take up moisture during the process of grinding and analysis, and in this respect the method was not satisfactory, since several corrections were necessary. Extracting the chicken with ether and then drying and grinding the residue was tried and found to be complicated and liable to error on account of changes in moisture. The method finally adopted was to grind the entire chicken as finely as possible through a meat chopper, with the addition of about 1 per cent boric acid. The sample was left in cold storage and the analysis made by three different analysts as quickly as possible. There was some difficulty due to liquid settling out after three or four days. This method has since been improved by the addition of ground filter paper at the time of preparation, which not only enables the sample to be ground more finely, but also prevents liquid from settling out. This improvement had not been devised at the time the work here reported was completed.

Nitrogen was determined by the Kjeldahl-Gunning method on 3.5 gm portions. In all the analyses, protein was considered to be nitrogen x 6.25. Fat was determined on 4 gm portions by extraction with ether after drying under reduced pressure at 100°C. and grinding in a mortar. Calories were calculated by multiplying protein by 5.66 and ether extract by 9.35.

Details and Data of the Experiments

The results of eleven experiments are reported. In the first four experiments, 4 chickens were used in each of the two lots; in 5 experiments, 10 chickens were used in each lot; and in 2 experiments, 8 chickens were used per lot. Including the preliminary chicks used to ascertain their composition at the beginning of the experiment, the total number of chicks killed was 256.

The mixtures used in all the experiments were similar, but since the experiments were carried on over a period of several years, it was necessary to use several different lots of the same kind of feed. Table 1 shows the ingredients of mixtures used. The analyses of the feeds used for each mixture are given in Table 2. The composition of the mixtures was ascertained both by calculation from the data in Tables 1 and 2 and by analysis of the mixtures, and these are compared in Table 3. On the whole, the agreement is satisfactory.

Table 1. Ingredients of the mixtures, in per cent.

Laboratory number	Name of feed	Mixture 14	Mixture 18	Mixture 22	Mixture 23	Mixture 24	Mixture 25
33918	Yellow corn meal	51.0					
37338	Yellow corn meal			51.0	51.0		
39146	Yellow corn meal					51.0	
39393	Yellow corn meal						51.0
35916	Yellow corn feed meal		51.0				
35673	Wheat gray shorts	19.0	19.0				
37336	Wheat gray shorts			19.0	19.0		
39145	Wheat gray shorts					19.0	19.0
33972	Dried buttermilk	10.0					
35917	Dried buttermilk		10.0				
37340	Dried buttermilk			10.0	10.0	10.0	
39396	Dried buttermilk						10.0
35675	Cottonseed meal	6.0	6.0				
37337	Cottonseed meal			6.0			
37509	Cottonseed meal				6.0	6.0	
39412	Cottonseed meal						6.0
33973	Alfalfa leaf meal	5.0	5.0	5.0	5.0		
37641	Alfalfa leaf meal					5.0	5.0
32790	Tankage	4.0	4.0	4.0	4.0	4.0	
39395	Tankage						4.0
33303	Bone meal	2.0	2.0	2.0	2.0	2.0	2.0
33304	Oyster shell	2.0	2.0				
37339	Oyster shell			2.0	2.0	2.0	2.0
	Salt	1.0	1.0	1.0	1.0	1.0	1.0
	Cod liver oil						0.1

Table 2. Percentage composition of ingredients of mixtures.

Laboratory number	Name of feed	Protein	Ether extract	Crude fibre	Nitrogen free extract	Water	Ash
33918	Yellow corn meal	10.20	4.40	2.64	72.07	9.43	1.26
37338	Yellow corn meal	9.86	4.10	1.82	73.89	9.19	1.14
39146	Yellow corn meal	10.05	4.12	2.21	70.75	11.69	1.18
39393	Yellow corn meal	9.62	3.49	2.50	70.59	12.29	1.51
35916	Yellow corn feed meal	9.86	4.21	2.02	71.04	11.58	1.29
35673	Wheat gray shorts	18.25	4.52	6.77	55.45	10.38	4.63
37336	Wheat gray shorts	20.08	4.88	6.45	53.34	10.68	4.57
39145	Wheat gray shorts	19.32	4.91	5.81	55.23	10.31	4.42
33972	Dried buttermilk	47.33	8.60	.18	31.55	5.97	6.37
35917	Dried buttermilk	33.44	5.23	.76	38.69	11.03	10.85
37340	Dried buttermilk	37.10	6.06	.69	27.85	13.51	14.79
39396	Dried buttermilk	34.78	5.72	.22	42.13	6.39	10.76
35675	Cottonseed meal	42.47	7.50	10.16	27.32	6.68	5.87
37337	Cottonseed meal	46.34	7.87	9.98	23.81	5.72	6.28
37509	Cottonseed meal	47.33	6.21	9.70	24.20	6.40	6.16
39412	Cottonseed meal	45.35	7.72	10.70	24.53	5.74	5.96
33973	Alfalfa leaf meal	20.68	2.34	16.67	42.56	7.41	10.34
37641	Alfalfa leaf meal	21.79	3.17	17.27	40.71	5.70	11.36
32790	Tankage	51.89	9.20	1.59	3.15	5.21	28.96
39395	Tankage	59.21	8.36	1.54	2.46	5.88	22.55
33303	Bone meal	25.56	1.73	0	4.51	6.37	61.83

The effective organic constituents are also given in Table 3. These consist of the sum of the protein, the ether extract multiplied by 2.25, and the nitrogen-free extract. The ash, water, and crude fiber are considered to have no value as sources of energy in chicken feeds.

Table 3. Percentage composition of mixtures as calculated from the ingredients and analyses in Tables 1 and 2 and as found by analysis, and effective organic constituents.

	Mix. No.	Protein	Ether extract	Crude fibre	Nitrogen free extract	Water	Ash	Effective organic constituents
Found	14	19.65	5.05	4.00	55.56	8.30	7.44	86.6
Calculated	14	19.56	4.93	4.16	55.31	8.49	7.55	....
Found	18	18.55	4.64	3.90	56.18	8.93	7.80	....
Found	18	18.56	4.70	3.79	55.78	9.17	8.00	....
Found	18	18.77	4.66	3.72	56.55	8.31	7.99	....
Found	18	18.83	4.62	3.84	56.32	8.58	7.81	....
Average (4)	.....	18.68	4.66	3.81	56.21	8.75	7.90	85.4
Calculated	18	18.01	4.50	3.90	55.43	10.07	8.09	....
Found	22	19.22	4.42	3.79	55.13	9.10	8.34	....
Found	22	19.64	4.60	3.73	55.37	7.97	8.69	....
Average (2)	.....	19.43	4.51	3.76	55.25	8.54	8.52	84.8
Calculated	22	18.96	4.62	3.72	54.98	9.31	8.43	....
Found	23	19.31	4.51	3.85	55.35	8.37	8.61	84.8
Calculated	23	19.02	4.52	3.70	55.00	9.36	8.42	....
Found	24	18.75	4.43	3.99	53.24	10.53	9.06	82.0
Calculated	24	19.03	4.57	3.80	53.67	10.48	8.45	....
Found	25	18.90	4.50	3.92	55.39	8.69	8.60	84.4
Calculated	25	18.75	4.26	3.96	55.00	10.07	7.96	....

The digestion coefficients of the mixtures, as found by digestion experiments similar to those used in the other parts of this work, are given in Table 4. This table also contains the digestibility calculated from the constituents of the mixtures and digestion coefficients (also given in Table 5) taken from Texas Bulletin 372 (12). The digestibility of the protein and nitrogen-free extract of the mixtures as found by experiment are appreciably lower than the digestibility calculated by use of the coefficients in Table 5. Part of these differences may be due to the fact that the coefficients of digestibility in Bulletin 372 are averages of individual experiments, which vary; and some deviation of an individual experiment from the average is to be expected. It is also possible that young chickens digest somewhat differently from the older ones used to secure the coefficients of digestibility employed in the calculations. Table 4 also contains the effective digestible nutrients, which are the digestible protein, plus the digestible ether extract multiplied by 2.25, and the digestible nitrogen-free extract. The digestible crude fiber is not considered to be of value as a source of energy for chickens.

The live weight, empty weight, weight after preparation, the percentage of protein and fat, and the calories per 100 gm calculated from the composition are given for each chicken in Table 6. The empty weight is the weight of the chicken after the contents of the intestinal tract have been removed. There is always some loss in preparation of the sample, due to adhesion to the feed chopper and other things with which the sample comes into contact during the preparation, and also possibly due, in small part, to evaporation of water. The percentage of protein and fat are on the original basis, after correction has been made for the

Table 4. Digestion coefficients as found by experiment and as calculated from assumed digestibility of the ingredients as given in Table 5, effective digestible nutrients and estimated metabolizable energy.

	Mix	Protein	Ether extract	Crude fibre	Nitrogen free extract	Effective digestible nutrients, per cent of feed	Estimated metabolizable energy, calories per gram
D. E. 96	14	72.72	87.58	5.91	74.94	65.8	2.70
Calculated	......	77.56	86.04	11.30	81.90	....	....
Difference	......	—4.84	+1.54	—5.39	—6.96	....	....
D. E. 98	18	73.53	89.29	12.01	76.31	....	....
D. E. 99	18	71.78	90.32	13.16	78.32	....	....
D. E. 100	18	66.34	86.24	0	73.08	....	....
D. E. 101	18	66.39	86.31	2.34	75.09	....	....
Average (4)	......	69.51	88.04	6.88	75.70	64.8	2.66
Calculated	......	77.29	86.22	11.02	81.91	....	....
Difference	......	—7.78	+1.82	—4.14	—6.21	....	....
D. E. 102	22	73.88	95.54	15.34	76.32	....	....
D. E. 103	22	73.37	93.23	16.62	77.50	....	....
D. E. 104	22	71.80	94.14	12.56	77.79	....	....
D. E. 105	22	72.45	93.29	6.95	76.08	....	....
Average (4)	......	72.88	94.05	12.87	76.92	66.2	2.71
Calculated	......	75.26	81.80	10.22	83.89	....	....
Difference	......	—2.38	12.25	2.65	—6.97	....	....
D. E. 106	23	69.07	93.74	17.89	78.75	....	....
D. E. 107	23	71.36	92.97	12.80	78.38	....	....
Average (2)	......	70.22	93.36	15.35	78.57	66.5	2.73
Calculated	......	75.24	86.73	10.27	83.89	....	....
Difference	......	—5.02	6.63	5.08	—5.32	....	....
D. E. 108	24	70.33	95.19	19.87	77.00	....	....
D. E. 109	24	66.56	89.19	21.62	76.11	....	....
Average (2)	......	68.45	92.19	20.75	76.56	62.8	2.58
Calculated	......	75.20	85.78	10.66	83.64	....	....
Difference	......	—6.75	6.41	10.09	—7.08	....	....
D. E. 110	25	65.76	85.70	11.57	78.58	66.5	2.73
Calculated	......	75.31	85.68	10.61	83.60	....	....
Difference	......	—9.55	.02	.96	—5.02	....	....

Table 5. Digestion coefficients used for the individual feed (from Texas Bul. 372).

	Protein	Ether extract	Crude fibre	Nitrogen free extract
Corn feed meal	71.8	91.6	15.2	91.9
Dried buttermilk	81.6	78.6	....	81.1
43% Protein cottonseed meal	76.1	86.2	11.9	85.7
Alfalfa meal	63.4	21.8	1.4	34.4
Wheat gray shorts	69.2	85.2	13.0	71.0
Tankage	85.3	95.9	4.0	43.5
Bone meal	86.7	93.1	24.0	34.0

quantity of boric acid added. Small percentages of nitrogen-free extract are sometimes present, if estimated by difference, but this is not given or considered. In averaging the calories per gram of the preliminary chicks, occasionally one of the chicks is omitted, on account of it deviating too far from the others. Those omitted are marked in the tables. The calorie contents of the chicks at the beginning are calculated from the analyses of the preliminary chicks. The average calorie content of these chicks is multiplied by the average empty weight and this is divided by the live weight to secure the average calorie content per gram of live weight. The calorie content of the other chicks at the beginning of the experiment is calculated by multiplying the live weight at the beginning by the calorie content per gram of live weight of the preliminary chicks.

The average data of the experiments are summarized in Tables 10 and 11. These data are used to calculate the average maintenance requirements of the chicks and the average productive energy of the feed. Detailed data are given in Tables 6, 15, and 18.

Table 6. Composition, weights and calories per 100 grams for individual chickens.

Series and Laboratory number	Live weight at beginning gm.	Live weight at end gm.	Empty weight at end gm.	Per cent empty weight of live weight	Weight after preparation gm.	Protein per cent	Fat per cent	Calories, per 100 gm. empty weight
Series 50								
Preliminary								
35686	....	56.1	49.5	88.24	47.3	17.80	7.25	175.5
35687	....	50.0	41.7	83.40	40.5	17.36	6.59	165.3
35688	....	55.1	49.0	88.93	46.1	16.65	7.44	172.4
35689	....	49.8	44.1	88.55	42.5	17.33	6.16	159.5
Average	....	52.8	46.1	88.57	....	17.29	6.86	171.1
Calories per 100 grams	....	151.5	....	....	....	....	....	....
Full feed								
35715	49.7	144.1	136.5	94.73	134.3	20.00	10.31	211.5
35716	56.8	174.5	165.1	94.61	161.3	19.82	11.77	227.5
35717	52.4	152.5	141.0	92.46	138.5	20.74	8.99	206.3
35718	59.8	188.9	182.8	96.77	175.0	20.00	10.41	219.8
Average	54.7	165.0	156.4	94.64	....	20.14	10.37	216.3
Limited feed								
35719	55.8	117.5	112.1	95.40	110.0	19.61	7.27	184.6
35720	53.2	114.1	103.4	90.62	102.2	20.31	7.00	186.4
35721	52.2	110.0	103.5	94.09	102.9	19.15	5.54	171.1
35722	54.5	112.1	101.5	90.54	95.5	20.81	5.48	176.0
Average	53.9	113.4	105.1	92.66	....	19.97	6.32	179.5
Series 51								
Preliminary								
35738	....	60.5	53.6	88.60	51.3	17.75	7.80	179.0
35739	....	52.3	46.8	89.48	45.6	18.08	6.57	166.8
35740	....	62.1	56.5	90.98	53.2	17.12	9.16	187.6
35741	....	59.5	53.6	90.08	52.4	18.37	7.24	171.7
Average	....	58.6	52.6	89.79	....	17.83	7.69	176.3
Calories per 100 grams	....	158.3	....	....	....	....	....	....
Full feed								
35771	53.3	171.9	156.5	91.04	150.9	19.86	8.57	197.0
35772	62.3	202.1	172.4	85.30	170.5	19.71	9.06	199.9
35773	56.0	185.9	174.0	93.60	173.0	20.67	10.18	212.6
35774	64.6	185.8	172.0	92.57	169.8	20.33	9.22	202.2
Average	59.1	186.4	168.7	90.63	....	20.14	9.26	202.9
Limited feed								
35787	61.6	124.5	106.1	85.22	104.3	20.84	4.63	169.2
35788	57.4	118.2	103.6	87.65	102.1	20.78	4.85	167.6
35789	59.8	132.4	121.1	91.47	117.6	20.29	4.22	162.6
35790	53.3	113.9	104.5	91.75	100.2	20.29	3.89	160.7
Average	58.0	122.3	108.8	89.02	....	20.55	4.40	165.0

Table 6—continued. Composition, weights and calories per 100 grams for individual chickens.

Series and Laboratory number	Live weight at beginning gm.	Live weight at end gm.	Empty weight at end gm.	Per cent empty weight of live weight	Weight after preparation gm.	Protein per cent	Fat per cent	Calories, per 100 gm. empty weight
Series 52								
Preliminary								
35935	....	51.0	45.7	89.61	42.4	16.53	6.53	154.6
35936	....	48.0	43.5	90.63	42.3	16.98	6.40	156.0
35937	....	40.7	37.2	91.40	34.7	16.65	5.39	144.6*
35938	....	49.2	45.8	93.09	44.2	16.99	6.73	160.0
Average	....	47.2	43.1	91.18	....	16.79	6.26	156.6
Calories per 100 grams	....	142.7	....	....	....	....	....	....
Full feed								
36083	50.5	377.0	352.4	93.47	342.0	21.20	9.10	205.1
36084	49.0	320.6	299.8	93.51	291.0	21.82	10.16	218.5
36085	45.4	372.1	356.5	95.81	347.2	21.52	8.34	199.8
36086	45.7	303.1	288.5	95.18	283.5	21.88	5.85	178.5
Average	47.7	343.2	324.3	94.49	....	21.61	8.36	200.5
Limited feed								
36095	49.6	194.5	170.0	87.40	166.2	23.00	3.51	163.0
36096	49.0	214.7	191.8	89.33	186.5	22.02	5.44	175.5
36097	41.8	168.5	156.1	92.64	152.0	22.90	2.44	152.4
36098	47.1	191.7	179.2	93.48	174.0	23.07	2.64	155.3
Average	46.9	192.4	174.3	90.71	....	22.75	3.51	161.5
Series 53								
Preliminary								
36151	....	68 0	61.5	90.44	59.2	17.51	8.99	183.2
36152	....	64.9	59.3	91.37	57.6	18.49	7.05	170.6*
36153	....	74.1	65.8	88.80	63.2	18.77	8.85	189.0
36154	....	67.6	58.9	87.13	57.1	18.07	8.71	183.7
Average	....	68.7	61.4	89.44	....	18.21	8.40	185.3
Calories per 100 grams	....	165.7	....	....	....	....	....	....
Full Feed								
36262	72.6	361.5	347.0	95.99	337.8	21.45	9.93	214.3
36264	62 7	355.0	333.0	93.80	327.8	21.34	10.18	216.0
36265	71 1	311.0	294.2	94.60	296.5	22.38	6.90	191.2
36266	64.9	368.0	350.2	95.16	342.3	21.39	11.73	230.8*
Average	67.8	348.9	331.1	94.89	....	21.64	9.69	213.0
Limited feed								
36275	70.0	211.3	188.0	88.97	183.2	21.83	3.96	160.6
36276	67.1	214.5	191.5	89.28	187.4	22.75	3.70	163.4
36277	70.0	197.8	174.5	88.22	169.2	21.80	2.84	149.9
36278	63.0	194.3	183.8	94.60	184.0	22.11	3.83	161.0
Average	67.5	204.5	184.5	90.27	....	22.12	3.58	158.7
Series 55								
Preliminary								
37354	....	50.2	45.4	90.44	42.1	17.80	8.41	179.4
37355	....	49.4	43.5	88.06	41.2	17.44	6.29	157.5
37356	....	53.4	46.5	87.08	44 2	17.26	7.04	163.5
37357	....	45.4	39.4	86.78	37.2	16.25	6.03	148.4
Average	....	49.6	43.7	88.09	....	17.19	6.94	162.2
Calories per 100 grams	....	143.4	....	....	....	....	....	....
Full feed								
37372	56.4	195.0	181.9	93.28	172.2	20.85	9.33	205.3
37373	51.3	225.5	205.7	91.22	201.7	20.18	13.58	241.2
37374	54.0	216.2	199.5	92.28	194.5	20.75	9.62	207.4
37375	58.4	234.2	220.8	94.28	213.5	19.46	12.10	223.3
37376	47.1	190.5	181.2	95.12	175.9	20.58	11.39	223.0
37377	55.5	240.7	223.0	92.65	213.7	20.73	10.95	219.7
37378	42.6	162.7	153.2	94.16	151.5	20.87	11.67	227.2
37379	41.2	173.7	165.5	95.28	161.7	19.52	12.53	227.6
37380	54.8	214.5	201.7	94.03	194.3	21.00	11.57	227.0
37381	56.5	193.9	182.7	94.22	176.9	21.43	10.91	223.3
Average	51.8	204.7	191.5	93.65	....	20.54	11.37	222.5
Limited feed								
37382	56.2	121.2	108.5	89.52	105.2	21.03	7.27	187.0
37383	50.3	121.8	108.2	88.83	105.5	20.50	4.85	161.4
37384	54.2	114.7	103.0	89.80	99.3	20.95	3.98	155.8
37385	58.9	112.9	101.5	89.90	97.8	20.85	3.08	146.8

*Omitted from average.

Table 6—continued. Composition, weights and calories per 100 grams for individual chickens.

Series and Laboratory number	Live weight at beginning gm.	Live weight at end gm.	Empty weight at end gm.	Per cent empty weight of live weight	Weight after preparation gm.	Protein per cent	Fat per cent	Calories, per 100 gm. empty weight
Limited feed—continued								
37386	47.0	126.7	112.5	88.79	106.2	21.25	4.47	162.1
37387	55.5	106.3	96.5	90.78	91.8	21.38	3.82	156.7
37388	41.4	113.7	101.2	89.01	95.5	20.40	6.44	175.7
37389	41.4	123.5	102.5	83.00	99.1	20.60	6.45	176.9
37390	56.2	119.2	105.2	88.26	99.2	21.24	4.56	162.9
37391	56.2	111.8	104.8	93.74	100.7	21.31	3.47	153.1
Average	51.7	117.2	104.4	93.65	....	20.95	4.84	163.8
Series 56								
Preliminary								
37448	....	43.7	40.0	91.53	37.3	15.44	7.38	156.4
37449	....	47.7	41.9	87.84	39.8	17.57	6.85	163.5
37450	....	51.5	47.5	92.23	45.5	16.64	8.28	171.6
37451	....	46.6	41.5	89.06	39.5	16.86	7.21	162.8
Average	....	47.4	42.7	90.17	....	16.63	7.43	163.6
Calories per 100 grams	....	147.6	....	....	....	....	....	....
Full feed								
37471	45.0	169.6	166.5	98.17	159.3	20.40	10.58	214.4
37472	44.9	199.5	188.5	94.49	181.5	20.18	9.19	200.2
37473	51.5	235.2	217.0	92.26	210.4	19.74	9.90	204.3
37474	49.4	201.1	186.3	92.64	181.0	20.56	10.47	214.3
37475	52.9	166.7	153.5	92.08	146.4	22.39	8.58	207.0
37476	48.2	210.2	196.9	93.67	186.6	21.21	10.94	222.3
37477	45.4	187.4	175.5	93.65	167.4	20.68	8.24	194.1
37478	51.0	183.8	170.5	92.76	161.5	20.78	8.34	195.6
37479	49.5	201.8	190.7	94.50	181.6	20.55	9.71	207.1
37480	42.3	196.2	185.8	94.70	176.9	21.35	10.36	217.3
Average	48.0	195.2	183.1	....	....	20.78	9.63	207.7
Limited feed								
37481	45.3	114.7	99.0	86.31	95.3	21.02	5.11	166.8
37482	45.4	113.6	98.5	86.71	93.5	20.66	4.50	159.0
37483	51.0	104.7	93.0	88.83	89.5	21.77	3.35	154.5
37484	48.2	113.0	103.2	91.33	98.9	20.89	5.07	165.6
37485	52.2	105.7	94.7	89.59	91.5	21.50	3.45	154.0
37486	48.4	100.2	90.2	90.02	87.5	21.90	3.31	154.9
37487	52.2	116.2	103.2	88.81	97.3	20.47	4.32	156.3
37488	50.0	109.8	98.2	89.44	89.9	20.51	5.26	165.3
37489	49.5	119.8	106.5	88.90	100.4	20.88	3.80	153.7
37490	42.8	106.3	93.7	88.15	88.1	21.66	2.80	148.8
Average	48.5	110.4	98.0	....	....	21.13	4.10	157.9
Series 57								
Preliminary								
37568	....	56.5	49.1	86.90	48.0	16.79	8.56	175.1
37569	....	50.8	44.7	87.99	42.3	16.98	8.44	175.0
37570	....	52.5	49.0	93.33	46.2	17.76	9.39	188.3
37571	....	55.4	50.1	90.43	47.0	17.97	8.57	181.8
Average	....	53.8	48.2	89.66	....	17.38	8.74	180.1
Calories per 100 grams	....	161.6	....	....	....	....	....	....
Full feed								
37620	51.1	448.0	426.5	95.20	404.2	23.00	9.67	220.6
37621	52.1	375.5	359.6	95.77	339.5	22.97	11.40	236.6
37622	54.0	434.5	400.7	92.22	380.0	23.10	7.48	200.7
37623	53.0	464.2	440.0	94.79	418.7	22.31	11.72	235.9
37624	56.5	431.0	400.7	92.97	382.3	22.40	9.79	218.3
37625	52.4	402.5	356.5	88.57	346.5	23.60	7.84	206.9
37626	49.4	391.5	370.2	94.56	354.2	23.28	9.40	219.7
37627	50.0	534.0	492.1	92.15	469.3	22.01	10.99	227.3
37628	54.6	464.5	394.5	84.93	376.7	21.57	7.87	195.7
37629	52.5	438.0	406.7	92.85	393.6	21.56	12.77	241.4
Average	52.6	438.4	404.8	92.40	....	22.58	9.89	220.3
Limited feed								
37630	51.8	147.1	135.5	92.11	129.7	22.30	3.27	156.8
37631	52.1	173.0	158.5	91.62	153.1	22.43	3.95	163.9
37632	54.0	157.2	142.5	90.65	135.8	23.55	3.20	163.2
37633	50.0	139.1	128.2	92.16	127.0	22.06	3.08	153.7
37634	56.6	181.2	172.5	95.20	168.6	22.42	2.98	154.8
37635	52.4	155.5	145.2	93.38	139.3	22.51	2.47	150.5

Table 6—continued. Composition, weights and calories per 100 grams for individual chickens.

Series and Laboratory number	Live weight at beginning gm.	Live weight at end gm.	Empty weight at end gm.	Per cent empty weight of live weight	Weight after preparation gm.	Protein per cent	Fat per cent	Calories, per 100 gm. empty weight
Limited feed—continued								
37636	50.4	205.5	193.0	93.92	191.3	22.85	3.67	163.6
37637	52.5	167.3	158.2	94.56	153.6	23.18	2.97	159.0
37638	55.3	173.9	161.0	92.58	155.4	22.18	3.74	160.5
37639	52.1	176.2	167.5	95.06	162.0	22.27	4.08	164.2
Average	52.7	167.6	156.2	93.12	....	22.58	3.34	159.0
Series 58								
Preliminary								
37689	....	65.5	57.8	88.24	50.1	18.49	8.80	186.9
37690	....	68.5	60.8	88.76	56.3	18.57	8.76	186.6
37691	....	64.2	57.5	89.56	53.1	18.23	11.10	207.0*
37692	....	66.5	63.5	95.49*	58.7	18.72	8.65	186.8
Average	....	66.2	59.9	88.85	....	18.50	9.36	186.8
Calories per 100 grams	....	166.1	....	....	....	....	....	....
Full feed								
37702	65.0	223.7	211.1	94.37	204.3	20.02	10.26	209.2
37703	68 2	220.8	211.5	95.79	204.3	20.86	10.18	213 3
37704	62.5	201.5	188.8	93.70	178.9	20.88	9.96	211.3
37705	66.8	163.0	158.7	97.36	154.5	23.84	6.96	200.0
37706	65.8	243.2	226.5	93 13	221.4	20.98	8.07	194.2
37707	62.5	204.5	192.1	93.94	190.5	20.06	9.03	198.0
37708	68.5	233.0	228.5	98.07	225.0	21.06	10.20	215.3
37709	61.9	209.5	200.5	95.70	196.8	20.80	9.40	205.6
37710	64.0	186.5	170.5	91.42	165.2	21.55	6.64	184.1
37711	66.5	221.0	208.7	94.43	204.5	20.98	8.32	196.5
Average	65.2	210.7	209 7	94.79	....	21.10	8.91	202.8
Limited feed								
37712	64.8	113.3	101.5	89.59	96.8	21.56	3.51	154.9
37713	68.5	113.5	99.1	87.31	97.3	22.06	2.58	149.0
37714	61.6	106.2	94.6	89.08	92.4	21.42	3.57	154.6
37715	67.4	96.5	86.2	89.33	83.8	22.15	1.53	139.7
37716	65.8	105.7	94.1	89.03	92.4	21.95	3.33	155.4
37717	63.0	117.0	105.1	89.83	101.1	21.60	2.67	147.2
37718	67.0	99.3	87 8	88.42	83.2	21.72	1.71	138.9
37719	60.0	105.2	97.0	92.21	94.4	21.88	2.68	148.9
37720	64.5	111.4	96.6	86.71	94.8	21.40	3.33	152.3
37721	66.5	117.7	103.0	87.51	100.1	21.58	2.73	147.7
Average	64.9	108.6	96.5	88.90	....	21.73	2.76	148.9
Series 59								
Preliminary								
39222	....	57.2	50.8	88.81	46.0	16.59	6.90	148.4
39223	....	54.0	47.7	88.33	43.7	16.39	7.29	160.9
39224	....	50.2	44.7	89.04	41.5	17.57	7.22	167.0
39225	....	52.2	46.5	89.08	42.5	17.27	5.40	148.2
Average	....	53.4	47.4	88.82	....	16.96	6.70	156.1
Calories per 100 grams	....	138.6	....	....	....	....	....	....
Full feed								
39372	52.0	479.1	442.2	92.30	432.3	21.25	11.17	224.7
39373	49.9	411.2	383.0	93.14	374.7	22.43	7.97	201.5
39374	54.9	500.1	464.2	92.82	451.6	22.55	10.59	226.7
39375	51.2	550.1	507.8	92.31	495.0	22.02	7.55	195.2
39376	53.5	529.5	485.5	91.69	470.0	22.49	6.60	189.0
39377	58.0	574.2	544.2	94.78	527.6	21.52	9.20	208.6
39378	52.7	504.2	468.2	92.86	455.5	22.59	7.80	200.8
39379	55.3	534.5	495.5	92.70	482.8	21.82	9.21	209.6
39380	56.9	531.0	491.7	92.60	477.8	22.41	10.40	224.1
39381	51.8	463.3	430.0	92.81	421.0	21.90	10.09	218.3
Average	53.6	507.7	471.2	92.80	....	22.10	9.07	209.8
Limited feed								
39382	52.5	199.7	183.2	91.74	178.3	22.50	4.00	164.8
39383	50.0	204.2	189.5	92.80	180.7	23.03	2.57	154.4
39384	54.4	188.5	176.2	93.47	170.0	23.13	3.20	160.8
39385	51.3	212.0	193.7	91.37	187.4	24.22	3.10	166.1
39386	53.6	187.0	170.1	90.96	164.3	23.21	2.40	153.8
39387	53.6	183.7	172.5	93.90	167.6	23.53	2 68	158.2

*Omitted from average.

Table 6—continued. Composition, weights and calories per 100 grams for individua chickens.

Series and Laboratory number	Live weight at beginning gm.	Live weight at end gm.	Empty weight at end gm.	Per cent empty weight of live weight	Weight after preparation gm.	Protein per cent	Fat per cent	Calories, per 100 gm. empty weight
Limited feed—continued								
39388	57.0	201.5	188.7	93.65	183.8	22.14	2.32	147.0
39389	52.2	192 7	181.2	94.03	174.5	23 14	2.38	153.2
39390	55.2	183.5	171.1	93.24	164.3	23.43	4.15	171.4
39391	50.6	181.2	158.8	87.64	152.2	23.20	2.23	152.2
Average	53.0	193.4	178.5	92.28	....	23.15	2.90	158.2
Series 60								
Preliminary								
39427	....	45.8	41.3	90.17	39.3	15.96	6.98	155.6
39428	....	56.8	50.5	88.91	48.2	17.78	7.38	169.6
39429	....	....	....	....	....	....	....	....
39430	....	42.5	39.6	93.18	35.5	16.78	6.81	158.6
Average	....	48.4	....	90.75	....	16.84	7.06	161.3
Calories per 100 grams	....	146.5	....	....	....	....	....	....
Full feed								
39534	44.7	196.5	177.5	90.33	172.0	18.98	8.40	186.0
39535	47.5	144.0	132.2	91.81	128.0	19.68	7.93	185.5
39536	55.3	141.6	130.5	92.16	126.1	21.41	5.53	172.9
39537	50.2	173.5	161.5	93.08	156.5	20.10	8.23	190.7
39538	46.0	163.5	152.0	92.97	146.7	20.14	9.92	206.7
39539	41.3	145.2	135.1	93.04	131.0	20.44	9.85	207.8
39540	58.7	221.7	208.6	94.09	201.4	19 60	8.06	186.3
39541	38.5	150.2	142.0	94.54	134.5	19.74	8.28	189.2
Average	47.8	167.0	154.9	92.80	....	20 01	8.28	190.6
Limited feed								
39542	46.5	98.9	86.5	87.46	83.5	21 25	2.76	146 1
39543	49.2	104.0	90.7	87.21	88.1	21 35	4.71	164.9
39544	51.5	102.6	90.8	88.50	87.5	20 68	4.81	162.0
39545	49.7	100.8	85.5	84.82	82.0	19 69	6.32	170.5
39546	51.5	105 0	91.1	86.76	87.2	21.21	2.68	145.1
39547	47.2	108.5	93.8	86.45	89.0	20.34	3.45	147.4
39548	56.1	95.7	89.5	93.52	81.0	21.78	2.92	150.6
39549	34.5	96.5	91.2	94.51	86.5	19.64	8.02	186.2
Average	48.3	101.5	89.9	88.65	....	20.74	4.46	159.1
Series 61								
Preliminary								
39427	....	45.8	41 3	90.17	39.3	15.96	6.98	....
39428	....	56.8	50.5	88.91	48.2	17.78	7.38	....
39430	....	42.5	39.6	93.18	35.5	16.78	6.81	....
Average	....	48.4	....	90.25	....	16.84	7.06	....
Calories per 100 grams	....	146.5	....	....	....	....	....	....
Full feed								
39823	42.9	906.7	877.0	96.72	848.6	23.89	8.93	278.8
39824	44.8	862.1	827.5	95.99	802.5	22.91	12.86	249.9
39825	52.5	743.0	711.4	95.75	689.0	24.18	9.64	227 0
39826	53.8	766.9	734.5	95.78	713.0	23.68	6.78	197.4
39827	51.3	809.5	770.7	95.21	722.0	23.85	7.02	200.6
39828	44.2	941.0	903.5	96.01	878.2	25.82	6.02	202.4
39829	58.3	1170.5	1116.5	95.39	1076.0	23.28	8.69	213.0
39830	36.5	779.5	735.5	94.36	702.2	23.42	9.14	218.0
Average	48.0	872.4	834.6	95.65	....	23.88	8.64	223.4
Limited feed								
39831	45 5	472.5	346.5	73.33	334 9	24.12	2.53	160.2
39832	44.8	523.5	466.5	89.11	453.1	24 51	5.62	191.3
39833	54.8	507.5	452.5	89.16	436.3	24 28	5.40	187.9
39834	50.0	463.5	432.6	93 33	398.0	24 41	2.91	165.4
39835	48.2	496.0	449.5	90.63	436.5	24.19	4.61	180.0
39836	43.7	462.5	422.5	91.35	408.5	24.37	6 09	194.9
39837	58.2	515.4	461.5	89.54	441.5	23.87	5.85	189.8
39838	37.2	453.0	423.5	93.49	396.5	24.30	6.13	194.9
Average	47.8	486.7	444.1	90.94	....	24.26	4.89	183.0

The calories per gram of chicken were calculated from the analyses by multiplying the grams of protein by 5.66 and the grams of ether extract by 9.35. This method of calculation was checked on 15 samples of dried chickens by comparing the calories calculated with those found by use of the Emerson adiabatic oxygen bomb calorimeter (Table 7). All the figures given are averages of two or more determinations. Table 7 shows that on an average the calculated values are only one per cent lower than the values actually found by means of the calorimeter. On account of the small quantity of material used in the calorimeter and the much larger quantities used in the chemical analyses, we consider the method of calculating the calories from the analyses to be more accurate than the direct calorimetric determinations.

Table 7. Heat of combustion of dried chicken calculated from analyses and found by combustion in calories per gram.

Laboratory number	Analysis		Heat of Combustion		Difference between calculated and found
	Protein per cent	Fat per cent	Calculated Cal./gm.	Found Cal./gm.	
34005	61.52	21.72	5.51	5.59	.08
34006	56.26	26.97	5.71	5.83	.12
34009	59.59	25.16	5.73	5.85	.12
34010	62.27	20.93	5.48	5.63	.15
34011	61.73	20.66	5.43	5.48	.05
34012	69.59	12.19	5.08	5.23	.15
34013	66.33	14.87	5.14	5.30	.16
36176	59.91	23.32	5.57	5.51	—.06
37410	50.77	33.51	6.01	6.11	.10
37411	58.51	26.74	5.81	5.83	.02
37413	55.61	29.71	5.92	5.94	.02
37412	55.48	30.58	6.00	5.95	—.05
37414	56.42	29.36	5.94	5.93	—.01
37415	66.90	14.60	5.15	5.19	.04
37416	65.26	15.81	5.17	5.16	—.01
Average (15)	....	....	5.58	5.64	.06

The chickens were weighed weekly. The average weight may be taken to be the average of the first and last weighings, or it may be taken to be the average for each period. These two methods are compared, the first being termed "Average of first and last" weights and the second "Average weight by periods." The average weight for each week is the weight at the beginning and at the end of the week divided by two. If the weekly weighings for 3 weeks are designated by the letters a, b, c, d, the average weight for the first week would be $\frac{a + b}{2}$, for the second, $\frac{b + c}{2}$, and for the third, $\frac{c + d}{2}$. The average for the three weeks would be $\frac{a + 2b + 2c + d}{6}$, and not $\frac{a + b + c + d}{4}$. The average weights by periods are calculated by this procedure.

The surface area was calculated for each weight of each chicken by the formula of Southgate (27), $S = 9.3W^{2/3}$. The average surface by periods is calculated in the same way as the average weight by periods.

Variations in the Composition of the Chickens

As seen in Table 6, there are some differences in the rate of growth and the composition of the chickens fed on the same feed at the same time. There are also some differences in the composition of the chickens killed at the beginning of the experiment. Such variations are to be expected. A summary of the differences in composition of the chickens is given in Tables 8 and 9. The differences between the live weights of some of the chickens at the end of the same experiment are grater than is desirable, even though the chickens used were selected from a larger group. These differences are probably due to variation in the growth intensity due to the heredity of the animals and cannot be avoided. Some differences occur with the percentage of protein, but the differences in this respect between individual chickens of the same lot are comparatively small.

Table 8. Variations in energy content (calories) and live weights of chicks.

Series Number	Calories per 100 grams					Live weight at end—grams		
	Maximum	Minimum	Average	Standard deviation	Standard error	Maximum grams	Minimum grams	Average grams
Preliminary								
55	179.4	148.4	162.2	13.043	6.521	53.4	45.4	49.6
56	171.6	156.4	163.6	6.234	3.117	51.5	43.7	47.4
57	188.3	175.0	180.1	6.369	3.185	56.5	50.8	53.8
58	207.0*	186.6	186.8	.149	.086	68.5	64.2	66.2
59	167.0	148.2	156.1	9.346	4.673	57.2	50.2	53.4
Limited feed								
55	187.0	146.8	163.8	12.173	3.850	126.7	106.3	117.2
56	166.8	148.8	157.9	6.084	1.924	119.8	100.2	110.4
57	164.2	150.5	159.0	4.889	1.546	205.5	139.1	167.6
58	155.4	138.9	148.9	5.870	1.856	117.7	96.5	108.6
59	171.4	147.0	158.2	7.506	2.374	212.0	181.2	193.4
Full feed								
55	241.2	205.3	222.5	10.293	3.255	240.7	162.7	204.7
56	222.3	194.1	207.7	9.405	2.974	235.2	166.7	195.2
57	241.4	195.7	220.3	15.561	4.921	534.0	375.5	438.4
58	215.3	184.1	202.8	9.908	3.133	243.2	163.0	210.7
59	226.7	189.0	209.8	13.249	4.190	574.2	411.2	507.7

*Excluded from average.

The greatest differences between the individual chickens in the same group are found in the fat content. The differences are greater with the chickens fed on limited feed than with those fed on full feed or with the preliminary chickens. For example, the fat content of chickens on limited feed ranges from 2.53 to 6.13 per cent in Series 61, 1.53 to 3.57 per cent in Series 58, and 2.68 to 8.02 per cent in Series 60. For those on full feed, the range was from 6.60 to 11.17 per cent in Series 59, 6.90 to 11.73 in Series 53 and 5.85 to 10.16 per cent in Series 52. Evidently there are considerable differences in the ability of individual chickens to store fat.

While there are appreciable differences in calorie content (Table 8) between the chickens in the same group, these differences are not as wide as might be expected from the variations in fat content. The protein is usually low when the fat is high, thus tending to reduce the difference in calories. A variation of 2% from an average of 20% protein is not as great a percentage variation as a variation of 2% on 8% of fat. The percentage of protein is thus relatively constant. In many groups the differences between the maximum and minimum calorie content are less than 15 per cent of the average, and in some groups the

Table 9. Variations in protein and fat content of chicks.

Series Number	Protein					Fat				
	Maximum %	Minimum %	Average %	Standard deviation	Standard error	Maximum %	Minimum %	Average %	Standard deviation	Standard error
Preliminary										
55...........	17.80	16.25	17.19	.66	.33	8.41	6.03	6.94	1.07	.53
56...........	17.57	15.44	16.63	.89	.44	8.28	6.85	7.43	.61	.30
57...........	17.97	16.79	17.38	.58	.29	9.37	8.44	8.74	.44	.22
58...........	18.72	18.23	18.50	.21	.10	11.10	8.65	9.32	1.18	.59
59...........	17.57	16.39	16.96	.56	.28	7.29	5.40	6.70	.89	.44
Limited feed										
55...........	21.38	20.40	20.95	.36	.11	7.27	3.08	4.84	1.42	.45
56...........	21.90	20.47	21.13	.54	.17	5.26	2.80	4.10	.88	.28
57...........	23.55	22.06	22.58	.48	.15	4.08	2.47	3.34	.51	.16
58...........	22.15	21.40	21.73	.27	.08	3.57	1.53	2.76	.71	.22
59...........	24.22	22.14	23.15	.56	.18	4.15	2.23	2.90	.70	.22
Full feed										
55...........	21.43	19.46	20.54	.64	.20	13.58	9.33	11.37	1.27	.40
56...........	22.39	19.74	20.78	.73	.23	10.94	8.24	9.63	.99	.31
57...........	23.60	21.56	22.58	.72	.23	12.77	7.48	9.89	1.81	.57
58...........	23.84	20.02	21.10	1.06	.34	10.26	6.64	8.91	1.35	.43
59...........	22.59	21.25	22.10	.47	.15	11.17	6.60	9.07	1.52	48

differences are only about 10 per cent. There are a few other groups, however, in which the differences between the maximum and minimum calories are more than 15 per cent. In Series 61, in which the chickens were on full feed 84 or 85 days, the calories range from 197.4 to 278.7 per 100 grams, a difference of over 40 per cent. It is unfortunate that chickens vary so much, but this variation is natural and cannot be prevented at the present time.

Basis for Method of Calculating Distribution of Energy Between Maintenance and Productive Purposes

The productive energy of feed eaten by the chickens was used partly for maintenance and partly for gain. In order to calculate the productive energy of the feed, it is necessary to ascertain the distribution of the feed between maintenance requirements and gain. The maintenance requirements should be related to the basal metabolism. The basal metabolism of animals is generally considered to be in proportion to their surface area, or an exponential function of their weight. Mitchell et al. (24) state that "It is a matter of considerable significance that, for the cockerels and pullets, the basal heat production per square meter of body surface was remarkably constant for all age groups, except the youngest cockerels, while the basal heat production per kilogram of body weight decreased continuously with advancing age. This fact constitutes a formidable argument in favor of the body surface as a unit of reference for basal metabolism as opposed to the body weight." Whether the maintenance requirements are likewise in proportion to the body weight or to the surface is a question not yet decided, though it is frequently assumed that the latter is the case, as was done by Southgate (27) in experiments similar to these here reported. Mitchell and Hamilton (23) (p. 514), however, found that estimates of the maintenance requirements for swine were more satisfactory by the weight ratio than by the surface ratio, since by the surface ratio the maintenance requirements per 100 pounds of older pigs were greater than those for younger pigs, the opposite of what might reasonably be expected. As it was not possible to tell in advance whether the surface ratio or the weight ratio should be used in calculating the maintenance requirements of the chicks used in this work, both methods were tried.

Preliminary calculations of the productive energy from the average results were made by an algebraic method similar to that of Southgate (27) in which no assumptions were made regarding the productive energy of the feed consumed. These preliminary calculations were made from the average data in Tables 10 and 11. The chief assumption is that the maintenance requirements vary according to the weight or to the surface area for both lots in each experiment.

The equations used were

(1) $WM + G = FX$; (2) $VM + H = DX$.

In these equations, W equals weight or surface of chick on limited feed;
V is weight or surface of chick, full feed;
G is gain of energy in calories, limited feed;
H is gain of energy in calories, full feed;
F is feed eaten, limited feed;
D is feed eaten, full feed;
M is maintenance requirements for the period of the experiment per unit of weight or surface, in calories, and
X is productive energy of the feed in calories.

Solving for X and M:

$$X = \frac{VG - WH}{VF - WD} \qquad M = \frac{FX - G}{W} \text{ or } \frac{DX - H}{V}$$

The maintenance requirements per day (N) would be M/K, if K is the number of days of the experiment.

The productive energy values in calories per gram of the feed mixtures, as calculated by use of the above equations, with use of the weight basis and of the surface basis, are given in Table 14. We must here point out again that the chickens in each experiment were fed the same feed for the same period of time under the same conditions, the only difference being in the quantities of feed fed the two lots.

The data in Table 12 show that the productive energy calculated by the weight basis for maintenance is much higher than that calculated by the surface basis. The average productive energy for the 10 experiments calculated on the weight basis is 1.80 calories per gram of feed, while on the surface basis it is 1.33, a difference of 0.47 calories per gram. The difference is 26 per cent of the productive energy calculated on the weight basis.

Table 10. Summary of data from feeding tests, chicks on limited feed.

Series Number	Feed Mix. No.	Days of Exp.	Average weight by periods gm.	Average of first and last weights gm.	Average surface by periods cm.	Average of first and last surfaces cm.	Gain of energy cal.	Feed eaten gm.
50	14	21	77.7	83.5	168.2	175.3	107.2	152.4
51	14	21	81.4	90.2	173.3	184.2	87.7	163.7
55	22	21	75.9	84.5	165.0	175.8	97.0	164.7
56	22	21	71.7	79.5	158.9	168.4	83.3	165.7
58	23	21	83.6	86.8	177.1	180.9	36.0	167.6
60	24	21	69.9	74.9	156.6	162.5	72.3	171.0
52	18	42	114.9	119.7	216.3	215.3	215.6	460.3
53	18	42	122.0	136.0	225.9	238.5	181.2	476.8
57	23	42	104.4	110.2	203.6	206.5	163.6	430.8
59	24	42	112.1	123.3	211.9	221.1	208.9	488.7
61	25	84.5	214.2	268.5	318.8	348.8	723.3	1560.7

Table 11. Summary of data from feeding tests, chicks on full feed.

Series Number	Feed Mix. No.	Days of Exp.	Average weight by periods gm.	Average of first and last weights gm.	Average surface by periods cm.	Average of first and last surfaces cm.	Gain of energy cal.	Feed eaten gm.
50	14	21	108.0	109.9	207.4	206.7	256.4	272.1
51	14	21	112.6	122.8	211.2	222.2	249.2	307.7
55	22	21	121.8	128.3	223.8	225.8	351.9	361.5
56	22	21	114.0	121.6	214.2	217.7	309.7	360.9
58	23	21	136.3	137.9	242.6	239.7	297.5	411.4
60	24	21	99.8	107.4	196.2	201.5	225.2	316.8
52	18	42	168.9	195.5	274.6	288.8	583.3	849.9
53	18	42	198.7	208.4	309.6	307.6	595.9	933.2
57	23	42	212.9	245.5	319.6	333.3	808.2	1120.9
59	24	42	242.0	280.7	347.4	361.8	913.7	1291.0
61	25	84.5	400.5	460.2	478.6	484.9	1730.6	3066.8

An examination of the data in Table 12 shows that the productive energy calculated by the surface basis averaged 1.42 calories per gram when the period of experiment was 21 days, 1.21 calories per gram when the experiment was 42 days, and 0.89 calories per gram when the experiment lasted 84.5 days. Thus widely different values of the productive value of practically the same feed were secured when the surface basis for maintenance was used in the calculations. The surface basis in this respect is not a satisfactory basis for calculation of the productive energy.

Similar data secured by the weight basis of calculating maintenance are much more concordant. The average calories of productive energy per gram of the feed for the chickens on experiment 21 days is 1.77, nearly the same as 1.85, the figure for those on experiment 42 days. The value for the single 84.5 day experiment is much higher, being 2.54 calories per gram, but not nearly so different from the others as the corresponding value secured from this experiment by use of the surface basis for maintenance. The weight basis for figuring maintenance gives practically the same productive energy for the same feed when the chicks were fed 21 days and 42 days, while the surface basis gives an appreciably lower value for the same feed when the chicks were fed 42 days. The weight basis therefore seems to give more reasonable results in the calculations than the surface basis.

Table 12. Preliminary comparison of productive energy of feed and maintenance requirements of chicks calculated by the weight basis and by the surface basis.

Series No. and days on experiment	Feed Mix. No.	Number of chicks per lot	Average weight of chicks gm.	Productive energy calories per gram, calculated by			Maintenance requirements	
				Weight basis	Surface area basis	Energy production coefficients (corrected)	Weight basis, calories per kilogram per day	Surface basis, calories per sq. meter per day
21 days								
50.......	14	4	77.7	1.78	1.48	1.49	101	340
51.......	14	4	81.4	1.57	1.31	1.49	99	350
55.......	22	10	75.9	2.02	1.60	1.50	148	480
56.......	22	10	71.7	1.82	1.44	1.50	145	470
58.......	23	10	83.6	1.73	1.37	1 51	145	520
60.......	24	8	67.7	1.68	1.31	1.46	146	460
Average (6)..	....	....	....	1.77	1.42	1.49	131	440
42 days								
52.......	18	4	114.9	1.54	1.17	1.45	102	340
53.......	18	4	122.0	1.92	1.24	1 45	143	430
57.......	23	10	104.4	1.96	1.24	1.51	155	430
59.......	24	10	112.1	1.96	1.17	1.46	159	410
Average (4)..	....	....	....	1.85	1.21	1.47	140	400
84.5 days								
61	25	8	....	2.54	.89	1.46	179	250
Average (except 61) (10)	....	....	....	1.80	1.33	1.48	134	423

There are appreciable differences in the productive energy of the same mixture measured by different individual experiments, for example 1.78 in Exp. 50 and 1.57 in Exp. 51 for mixture 14. As will be shown later, these differences are, in part, caused by the method of calculation, since the algebraic method of calculation tends to increase the effect of small differences.

The higher average value for productive energy of the mixture obtained by use of the weight basis for calculating maintenance, 1.80 calories per gram, is in better accord with the productive value of 2.83 calories per gram for corn, obtained by Mitchell and Haines (22) in respiration experiments with hens, than the lower average value of 1.33 calories per gram calculated by the surface basis. These higher values secured on the weight basis are also in better accord than the lower values secured on the surface basis with the net energy values of 1.98 to 3.55 calories per gram of dry matter secured with various foods by Forbes, Swift, and Black (10) on experiments with rats.

The higher value obtained on the weight basis is also in better accord with the productive energy of 1.8 calories per gram for a mixture of dried whole milk and ground oats, calculated by Southgate (27) from experiments with fattening chickens similar to those described.

The above considerations indicate clearly that the weight basis for calculating maintenance is more nearly correct than the surface basis for the purposes of this work, when the results for the productive energy of the mixtures are considered.

We next need to consider the maintenance requirements as secured by use of the surface basis and the weight basis. The maintenance requirements corresponding to the productive energy values just discussed and calculated by the method already described, are given in Table 12. These values are not exactly correct, since the algebraic method of calculation gives different productive energy values to the same feed when used in different tests, but corrections for this will be made later. The maintenance requirements are here discussed in order to ascertain whether the weight basis or the surface basis should be used in calculating the maintenance requirements of the chicks and the productive energy of the feeds in the work here reported.

From the data in Table 12, it is seen that the average maintenance requirements of the 6 sets of chicks fed 21 days, calculated on the weight basis, are 131 calories of productive energy per kilogram for chicks weighing 69.9 to 83.6 grams. The average for the 4 sets on experiment for 42 days with average weights of from 104.4 to 122.0 gm is 140 calories per kilogram. These averages differ only 7 per cent. The average maintenance requirement calculated on the surface basis is 440 calories per square meter per day for the 21 day experiment and 400 calories for the 42 day experiment.

Table 13. Basal heat production of chickens, from Mitchell, et al (22).

Number of birds	Age	Weight	Heat produced daily	
			Per kilogram body weight	Per square meter body surface
	Days	Gm.	Cals.	Cals.
Chicks:				
5	1 to 6	33	146	575
1	13	25	169	669
3	15–17	31	207	832
Cockerels:				
4	37	283	166	1,441
6	76	683	96	832
5	122	1,324	81	864
5	184	1,928	71	859
6	242	2,705	63	864
6	340	2,728	62	856

These results may be compared with the basal heat production, reported by Mitchell et al. (20), part of which is given in Table 13. We must remember that our results in Table 12 are in terms of calories of productive energy of the feed, while those of Mitchell are in terms of calories of total energy of the body material. The average of 423 calories of productive energy per kilogram per day for maintenance found by the surface basis of calculation can be compared with the much higher value of 830 calories of basal metabolism obtained by Mitchell or 778 calories for mature hens reported by others (8). The 134 calories per kilogram (Table 12), found by the weight basis, can be compared with about 166 calories by Mitchell (Table 13) for small chicks or the 120 calories of basal metabolism per kilogram reported by Barrot and others (3) for Rhode Island Red chickens weighing 100 grams and being 20 days old. The average of 134 calories of productive energy per kilogram is equal to 74.4 grams per day of the feed mixture, which may be compared with the maintenance requirement of 42 grams of feed per day per kilogram as calculated from the results reported by Titus (28) for laying White Leghorn pullets, or the 46.5 gm per 1000 gm calculated from work of Brody, Fork, and Kempster (6) for laying hens. The pullets could be expected to have a lower maintenance requirement than the young chickens, as can be seen by the work of Mitchell in Table 13, already cited. The quantity of feed used for maintenance is in accord with what could be expected from previous work. Here again the calculations on the weight basis are more nearly in accord with previously recorded data than are those on the surface basis.

Table 14. Maintenance requirements per day per kilogram of weight.

Series Number	Feed Mix. No.	Productive energy Calories by periods	by first and last weights	by individual chicks, weights by periods	Total feed grams	Effective organic constituents grams	Effective digestible nutrients grams	Metabolizable energy Calories
50	14	102	95	103	57.0	49.4	37.5	154
51	14	121	109	122	67.5	58.5	44.4	182
55	22	127	114	128	70.1	59.4	46.4	190
56	22	145	131	145	79.7	67.6	52.8	217
58	23	154	148	154	84.4	71.6	56.1	230
60	24	157	147	157	88.5	72.6	55.6	228
Average (6)		135	124	135	74.5	63.2	48 8	200
52	18	122	117	123	70.0	59.8	45.4	186
53	18	128	115	128	72.9	62.3	47.2	194
57	23	143	135	144	78.4	66 5	52.1	214
59	24	137	125	137	78.5	64.4	49.3	202
Average (4)		133	123	133	75.0	63.3	48.5	199
61	25	113	90	113	63.9	53.9	42.5	174
Average except 61 (10)		134	124	134	74.8	63.3	48.7	200

In the attempt to separate the quantity of food used for maintenance from that used for growth, it has been necessary to assume that the maintenance requirements vary in proportion to the surface (a function of the weight) or in direct proportion to the weight. It is possible that the maintenance requirements of the chicks on restricted food intake are lower than the maintenance requirements of the chicks on full feed or that the quantity of feed fed affects its digestibility and utilization, but we have at present no method of testing this possibility. It is also possible that the maintenance requirements of the chickens on experiment for 42 days are lower than those for the 21 days experiment. However, neither the average maintenance requirements by the weight basis nor the surface basis indicate such a difference, and at present we can think of no other method of testing this possibility. The correction for differences in body weight may introduce errors, but such correction cannot be avoided in work of the kind here presented.

Everything considered, use of the weight basis for calculating the productive energy of feeds and maintenance requirements of chicks from our experiments gives more consistent results and results much more nearly in accord with our present knowledge than use of the surface basis. For this reason, in subsequent discussion the weight basis alone will be used. If better methods of calculation are discovered, this work can be recalculated, since the data are given.

It is a peculiar fact that while the basal metabolism of chickens is more nearly in proportion to the calculated surface area (24) than to the weight, on the other hand maintenance requirements seem to be more nearly in proportion to the weight than to the calculated surface area. It is also peculiar that the maintenance requirements, in terms of productive energy, do not appear to be widely different from the basal metabolism, although somewhat lower.

Calculation of Corrected Maintenance Requirements from the Data

Having decided that the weight basis of calculation gives the more probable values for productive energy, we will now confine the discussion of the productive energy and maintenance requirements to the results found by this method of calculation.

As previously shown, different energy values are secured for the same feed when the algebraic method is used, so that the preliminary calculations of maintenance requirements need correction so as to use the same productive energy for the same feed. The productive energy values of the mixtures calculated from the production coefficients given for chickens in Texas Bulletin 372, as given in Table 12 of this bulletin, are on an average 21 per cent lower than the values secured in the work here presented, when allowance was made for the difference in digestibility. The productive energy of the mixtures calculated from the production coefficients, as given in Table 12, were multiplied by 1.21 to give the corrected values now to be used in the final calculations, and these are given in Table 17, as calories per gram calculated by corrected energy production coefficients.

Another method of calculating the productive energy of the mixtures to be used in the final calculations is from the effective digestible nutrients. From the total percentage of effective digestible nutrients given in Table 4 and the productive energy found by the weight by period basis (Table

12), the average productive energy of one gram of effective digestible nutrients was calculated to be 2.76 calories per gram (No. 61 excluded). The corrected productive energy was calculated for the different mixtures by multiplying their content of effective digestible nutrients (energy) by 2.76. The average productive energy of the mixtures (1.76) so calculated was about .03 calories lower than the values secured by the use of production coefficients already referred to (1.79), which differences did not appear to be large enough to require recalculation of the calculations already made with the use of the slightly higher values secured by the use of the production coefficients.

These corrected values given in Table 17 were used to calculate the energy maintenance requirements and the corrected productive energy, the calculations being based on the average data given in Tables 10 and 11 and the data for the individual chicks. The method of calculation is different from the algebraic method used in the preliminary work. (See Table 15 for examples.) The total gain in energy (calories) of the chicks on limited feed (Table 10) is divided by the corrected productive energy in calories per gram of the feed eaten (Table 17). The dividend is the grams of feed required for the gain, and when this is subtracted from the total feed eaten, the difference is the feed used for maintenance during the experiment. This quantity of feed divided by the average weight of the chicken gives the grams of feed required for maintenance of one gram of chicken for the period of the experiment. The average weight of the chicks on full feed (Table 11) is multiplied by the grams of feed required for maintenance of 1 gram of chicken, and the product is the feed used for maintenance by the chicks on full feed. The total feed less the maintenance requirements is the quantity of feed available for gain, and the calories of gain divided by this figure gives productive energy of the feed in calories per gram of feed. This is the desired productive energy of the feed. See Table 18 for examples.

The grams of feed required for maintenance of 1 gram of chicken, divided by the number of days of the experiment, gives the feed requirement per day. This multiplied by the productive energy of the feed and by 1000, gives the maintenance requirements per kilogram per day in terms of calories of productive energy of the feed.

Corrected Maintenance Requirements

The maintenance requirements as calculated from the data are presented in several forms in Table 14. The productive energy in calories was calculated (a) from the average data in Tables 11 and 12, with weights by periods, (b) from average data and the average of the first and last weights of the chicks, and (c) by individual chicks (Table 15) and the averages of the individual calculations. When (a) the average weights by periods were used, the results were more uniform than (b) when first and last weights were used; so the use of the average weight by periods is better. The maintenance requirements calculated from the average data (a) are identical with the averages (c) of the calculations

Table 15. Maintenance requirements calculated for individual chickens.

	Average weight by periods gm.	Initial energy content cal.	Final energy content cal.	Gain of energy cal.	Feed eaten gm.	Feed equivalent of energy gained gm.	Feed for maintenance			Productive energy in calories per day per 100 gm.
							Total gm.	Per period per 100 gm.	Per day per 100 gm.	
Series 50, Feed 14										
35719	79.9	84.5	206.9	122.4	145.0	68.0	76.99	96.36	4.59	8.26
35720	77.7	80.5	192.7	112.2	157.9	62.3	95.59	123.02	5.86	10.54
35721	75.8	79.0	177.1	98.0	150.8	54.5	96.33	127.08	6.05	10.89
35722	77.4	82.5	178.7	96.2	155.8	53.4	102.38	132.27	6.30	11.34
Average (4)	77.7	....	....	107.1	152.4	....	....	119.69	5.70	10.26
Series 51, Feed 14										
35787	87.2	97.5	179.5	82.0	159.2	45.6	113.64	130.32	6.21	11.17
35788	80.5	90.9	173.6	82.8	169.5	46.0	123.51	153.43	7.31	13.15
35789	83.7	94.7	197.0	102.3	170.9	56.8	114.07	136.28	6.49	11.68
35790	74.1	84.4	167.9	83.5	155.2	46.4	108.79	146.82	6.99	12.58
Average (4)	81.4	....	....	87.7	163.7	....	....	141.71	6.75	12.15
Series 52, Feed 18										
36095	115.1	70.8	277.1	206.3	454.8	117.9	336.90	292.70	6.93	12.13
36096	121.1	69.9	336.6	266.7	464.5	152.4	312.12	257.74	6.14	10.74
36097	107.9	59.7	237.9	178.3	449.3	101.9	347.43	321.99	7.67	13.42
36098	115.3	67.2	278.2	211.0	472.7	120.6	352.12	305.40	7.27	12.72
Average (4)	114.9	....	....	215.6	460.3	....	....	294.46	7.00	12.25
Series 53, Feed 18										
36275	126.4	116.0	301.9	185.9	477.5	106.2	371.26	293.72	7.00	12.24
36276	124.5	111.2	312.9	201.7	491.5	115.2	376.26	302.22	7.20	12.59
36277	119.9	116.0	261.7	145.7	461.9	83.2	378.67	315.82	7.52	13.16
36278	117.2	104.4	295.8	191.4	476.1	109.4	366.71	312.89	7.45	13.04
Average (4)	122.0	....	....	181.2	476.8	....	....	306.16	7.29	12.76
Series 55, Feed 22										
37382	79.4	80.6	202.9	122.3	167.7	67.2	100.50	126.57	6.03	10.97
37383	77.0	72.1	174.6	102.5	169.4	56.3	113.09	146.87	6.99	12.73
37384	78.9	77.7	160.5	82.7	162.3	45.5	116.84	148.09	7.05	12.84
37385	78.8	84.5	149.0	64.6	156.7	35.5	121.23	153.85	7.33	13.33
37386	80.6	67.4	182.3	114.9	167.2	63.2	104.05	129.09	6.15	11.19
37387	70.2	79.6	151.2	71.7	160.3	39.4	120.93	172.27	8.20	14.93
37388	67.7	59.4	177.8	118.4	166.3	65.1	101.24	149.54	7.12	12.96
37389	69.1	59.4	181.3	122.0	166.6	67.0	99.59	144.12	6.86	12.49
37390	78.9	80.6	171.3	90.7	164.1	49.9	114.24	144.79	6.90	12.55
37391	78.2	80.6	160.4	79.8	166.4	43.9	122.55	156.71	7.46	13.58
Average (10)	75.9	....	....	97.0	164.7	....	....	147.19	7.01	12.76

Table 15. Maintenance requirements calculated for individual chickens—Continued.

	Average weight by periods gm.	Initial energy content cal.	Final energy content cal.	Gain of energy cal.	Feed eaten gm.	Feed equivalent of energy gained gm.	Feed for maintenance			Productive energy in calories per day per 100 gm.
							Total gm.	Per period per 100 gm.	Per day per 100 gm.	
Series 56, Feed 22										
37481	71.8	66.8	165.1	98.3	161.7	54.0	107.71	150.01	7.14	13.00
37482	71.7	67.0	156.6	89.7	167.2	49.3	117.94	164.49	7.83	14.26
37483	71.2	72.2	143.7	68.5	168.2	37.6	130.57	183.39	8.73	15.89
37484	72.4	71.1	170.9	99.8	163.9	54.9	109.04	150.61	7.15	13.02
37485	70.9	77.0	145.8	68.8	159.9	37.8	122.10	172.21	8.20	14.93
37486	69.2	71.4	139.7	68.3	160.5	37.5	122.96	177.69	8.46	15.40
37487	74.5	77.0	161.3	84.3	171.8	46.3	125.51	168.47	8.02	14.60
37488	71.0	73.8	162.3	88.6	164.5	48.7	115.85	163.17	7.77	14.14
37489	75.5	73.0	163.7	90.7	169.1	49.8	119.27	157.97	7.52	13.69
37490	68.6	63.1	139.4	76.3	170.0	41.9	128.09	186.72	8.89	16.18
Average (10)	71.7	......	......	83.3	165.7	......	......	167.47	7.97	14.51
Series 57, Feed 23										
37630	95.3	83.7	212.5	128.7	408.0	70.4	337.55	354.20	8.43	15.43
37631	110.2	84.2	259.8	175.6	451.1	95.9	355.17	322.30	7.67	14.04
37632	100.5	87.3	232.6	145.3	425.0	79.4	345.60	343.88	8.19	14.98
37633	94.0	80.8	197.0	116.2	389.0	63.5	325.51	346.29	8.25	15.09
37634	108.3	91.5	267.0	175.5	446.9	95.9	351.00	324.10	7.72	14.12
37635	101.5	84.7	218.5	133.9	406.2	73.1	333.06	328.14	7.81	14.30
37636	116.0	81.5	315.8	234.4	469.1	128.1	341.02	307.23	7.32	13.39
37637	110.4	84.8	251.5	166.7	428.6	91.1	337.53	305.73	7.28	13.32
37638	102.9	89.4	258.4	169.1	425.7	92.4	333.32	323.93	7.71	14.12
37639	105.0	84.2	275.0	190.9	458.0	104.3	353.71	336.87	8.02	14.68
Average (10)	104.4	......	......	163.6	430.8	......	......	329.27	7.84	14.35
Series 58, Feed 23										
37712	87.3	107.6	157.2	49.5	172.6	27.1	145.53	166.70	7.94	14.53
37713	88.4	113.8	147.6	33.9	174.7	18.5	156.20	176.70	8.41	15.40
37714	81.5	102.3	146.3	44.0	169.6	24.0	145.58	178.63	8.51	15.57
37715	78.7	112.0	120.4	8.5	158.0	4.6	153.38	194.89	9.28	16.98
37716	83.6	109.3	146.2	36.9	157.0	20.2	136.83	163.67	7.79	14.26
37717	88.9	104.6	154.7	50.1	174.2	27.4	146.83	165.16	7.87	14.39
37718	79.1	111.3	122.0	10.7	153.5	5.8	147.66	186.68	8.89	16.27
37719	80.7	99.7	144.4	44.8	169.0	24.5	144.54	179.11	8.53	15.61
37720	83.7	107.1	147.1	40.0	172.4	21.8	150.57	179.89	8.57	15.68
37721	84.2	110.5	152.1	41.6	174.5	22.8	151.75	180.23	8.58	15.71
Average (10)	83.6	......	......	36.0	167.6	......	......	177.17	8.44	15.44

Table 15. Maintenance requirements calculated for individual chickens—Continued.

	Average weight by periods gm.	Initial energy content cal.	Final energy content cal.	Gain of energy cal.	Feed eaten gm.	Feed equivalent of energy gained gm.	Feed for maintenance			Productive energy in calories per day per 100 gm.
							Total gm.	Per period per 100 gm.	Per day per 100 gm.	
Series 59, Feed 24										
39382	110.4	72.8	301.8	229.1	487.6	130.9	356.71	323.11	7.69	13.46
39383	111.8	69.3	292.6	223.3	503.6	127.6	376.03	336.34	8.01	14.01
39384	108.2	75.4	283.4	208.0	466.8	118.9	347.94	321.59	7.66	13.40
39385	121.2	71.1	321.7	250.6	512.0	143.2	368.80	304.29	7.25	12.68
39386	109.0	74.3	261.6	187.3	499.0	107.1	392.00	359.59	8.56	14.98
39387	108.5	74.3	273.0	198.7	470.0	113.5	356.47	328.54	7.82	13.69
39388	118.2	79.0	277.4	198.4	495.2	113.4	381.83	323.04	7.69	13.46
39389	117.7	72.4	277.6	205.3	505.4	117.3	388.10	329.74	7.85	13.74
39390	108.3	76.5	293.3	216.8	471.5	123.8	347.63	320.99	7.64	13.38
39391	107.8	70.1	241.6	171.5	475.4	98.0	377.40	350.09	8.34	14.59
Average (10)	112.1	......	......	208.9	488.7	......	......	329.73	7.85	13.74
Series 60, Feed 24										
39542	69.0	68.1	126.4	58.3	163.8	32.9	130.89	189.70	9.03	15.99
39543	70.6	72.1	149.6	77.5	171.8	43.8	128.03	181.35	8.64	15.29
39544	69.2	75.5	147.1	71.7	175.2	40.5	134.71	194.67	9.27	16.41
39545	68.6	72.8	145.8	73.0	173.6	41.2	132.36	192.95	9.19	16.26
39546	73.8	75.5	132.2	56.8	170.5	32.1	138.44	187.59	8.93	15.81
39547	73.2	69.2	138.2	69.1	174.6	39.0	135.57	185.21	8.82	15.61
39548	72.6	82.2	134.8	52.6	166.4	29.7	136.70	188.29	8.97	15.87
39549	62.3	50.5	169.8	119.2	171.8	67.4	104.44	167.64	7.98	14.13
Average (8)	69.9	......	......	72.3	171.0	......	......	185.92	8.85	15.67
Series 61, Feed 25										
39831	195.2	66.7	555.0	488.4	1428.8	275.9	1152.89	590.62	7.00	12.37
39832	228.3	65.6	892.3	826.7	1579.3	467.1	1112.24	487.18	5.77	10.20
39833	220.2	80.3	850.3	770.0	1547.9	435.0	1112.87	505.39	5.98	10.59
39834	210.9	73.3	715.4	642.1	1577.5	362.8	1214.71	575.97	6.82	12.06
39835	224.0	70.6	809.2	738.6	1604.0	417.3	1186.72	529.79	6.27	11.10
39836	206.4	64.0	823.3	759.3	1591.0	429.0	1162.01	562.99	6.66	11.79
39837	229.6	85.3	875.9	790.7	1585.0	446.7	1138.29	495.77	5.87	10.39
39838	199.3	54.5	825.2	770.7	1572.3	435.4	1136.86	570.43	6.75	11.95
Average (8)	214.2	......	......	723.3	1560.7	......	......	539.77	6.39	11.31

for individual chicks in 5 experiments, and differ less than 1 per cent from the other six. The laborious calculation by individuals gives practically the same results as the easier method of using the average data.

The grams of total feed used for maintenance are given in Table 14 and are average values for individual chicks. The average figure of 74.8 gms is higher than the 42 gms from data of Titus (28) and 46.5 from calculations of Brody et al. (6) for laying hens. However, young growing chicks can be expected to have higher maintenance requirements than laying hens.

The effective organic nutrients required for maintenance also are given in Table 14. The term "effective organic nutrient" is used to specify the sum of the protein, the fat multiplied by 2.25, and the nitrogen-free extract. The term "effective organic constituents" is used to distinguish it from the total organic constituents, which would include crude fiber also.

The effective digestible nutrients required for maintenance are also given in Table 14. The term "effective digestible nutrients" is used to signify the digestible protein plus the digestible fat multiplied by 2.25 and plus the digestible nitrogen-free extract. The digestible crude fiber is not included, and the term "effective digestible nutrients" is used to distinguish it from the total digestible nutrients, which include the crude fiber.

Metabolizable energy requirements for the maintenance are also given in Table 14. Since direct determinations of metabolizable energy were not made, the metabolizable energy was calculated on the assumption that the effective digestible constituents have a metabolizable energy of 4.1 calories per gram, which is Rubner's figure as quoted by Armsby (1). This is naturally only an estimate, which will be corrected by work now in progress. The average metabolizable energy of 200 is higher than the basal metabolism of 166 for chicks of approximately the same size as reported by Mitchell (22).

The wide differences in the maintenance requirements calculated from some of the experiments require discussion. Variations are shown in Table 16. In Experiment 50 (Table 14), the maintenance requirement is 102, while in Experiment 60 it is 157 calories per day per kilogram, a difference of nearly 50 per cent. There are no corresponding differences in the productive energy calculated from the data of these experiments, since in Experiment 50 the productive energy is 1.79 calories per gram and in Experiment 60 it is 1.72. The productive energy is calculated from data from chickens on limited feed and corresponding chickens on full feed. Since there is little difference in the productive energy, the factors which caused a high maintenance requirement in Experiment 60 and a low maintenance requirement in Experiment 50 must have affected the chickens on full feed and those on limited feed in the particular experiment in a similar way. Therefore the average differences in maintenance requirements between the two experiments were due to environmental conditions, which affected both lots of chickens in the same way. Possibly the temperature of the room in which the chickens were kept was lower, part of the time, in one experiment than in the other.

Table 16. Average maintenance requirements in productive energy, calories per kilogram per day, calculated from individual chickens, with standard deviation and standard error.

Series Number	Feed No.	Number of chickens	Maintenance requirements, calories per kilogram: Average	Maximum	Minimum	Standard deviation	Standard error
21 days							
50.......	14	4	102.6	113.4	82.6	13.7	6.9
51.......	14	4	121.5	131.5	111.7	8.9	4.4
55.......	22	10	127.6	149.3	109.7	11.3	3.6
56.......	22	10	145.1	161.8	130.0	11.1	3.5
58.......	23	10	154.4	169.8	142.6	8.5	2.7
60.......	24	8	156.7	164.1	141.3	7.2	2.5
Average (6)...	....	8	134.7	148.3	119.7	10.1	3.9
42 days							
52.......	18	4	122.5	134.2	107.4	11.4	5.7
53.......	18	4	127.6	131.6	122.4	4.2	2.1
57.......	23	10	143.5	154.3	133.2	7.0	2.2
59.......	24	10	137.4	149.8	126.8	6.6	2.1
Average (4)...	....	7	132.8	142.5	122.5	7.3	3.0
84.5 days							
61.......	25	8	113.1	123.7	103.0	8.4	3.0
Average (all) (11)......	....	7	132.0	144.0	119.1	8.9	3.5

In the different experiments, there was more variation in the average maintenance requirements of the chickens fed for 21 days than in the requirements of those fed for 42 days. It appears possible that younger chickens may be more sensitive to environment than the older ones. The kind and amount of feathers may have something to do with this.

The maintenance requirements were calculated for each individual chick on limited feed, as detailed in Table 15. The results are summarized in Table 16.

There are some wide differences in the average maintenance requirements between the several experiments. The standard deviation is greater with the younger chickens than with the older ones. The average standard deviation is 10.1 for the younger chicks and 7.3 for those on experiment 42 days. The standard error is quite low. The standard error, as could be expected, is lower where 10 chicks were used per lot, than where only 4 were used. It is evident that individual chickens differ appreciably in their power to use the energy of food.

Consideration of these data leads to the conclusion that the use of only a few individuals may give incorrect results. The basal metabolism varies considerably, even on the same individual, as shown by Barott et al. (3).

Corrected Productive Energy

The corrected productive energy of the mixtures is given in several terms in Table 17. The productive energy of the mixture, in calories per gram, was calculated from (a) the average data in Tables 13 and 14, using average weights by periods, (b) the same data using averages of the first and last weights, (c) individual chicks records in Table 18, the averages being given in Table 17, and (d) from the corrected energy production coefficients.

When the average weights per period were used, the results were more uniform than when the averages of the first and last weight were used, showing that the use of weights by periods is better.

The productive energy calculated from the average data is only slightly different from the average by individual chickens, indicating that the shorter method might be as good as the longer method.

The effective organic constituents have an average productive energy of 2.14 calories per gram. The effective digestible nutrients have an average value of 2.73 calories per gram for the chickens on 21 days experiment and 2.84 for chickens on 42 days, with an average of 2.78 calories per gram for all experiments. It appears that these averages could be used in calculating the productive energy of feeds similar to these used in this experiment; but the fact that the digestible nutrients of one kind of feed may have a different productive energy from those of another kind of feed must not be forgotten in connection with such calculations. They can be used for preliminary calculations, until differences in different kinds of feed have been ascertained by experimental work.

The calories of productive energy are on an average 67.6 per cent of the estimated metabolizable energy, or one calorie of productive energy requires 1.48 calories of metabolizable energy.

The average productive energy calculated from the energy production coefficients given in Bulletin 372 is 1.48. If we use the productive energy of 1.80, the results secured are 122% of the assumed values used in Bulletin 372.

The mixture used consists of 51% of yellow corn meal, 19% wheat gray shorts, 10% dried buttermilk, 6% cottonseed meal, 4% tankage, 2% bone meal, 2% oyster shell, and 1% salt. On an average, the factors for productive energy of the feeds used in the mixture, as given in Texas Bulletin 372, should be multiplied by 1.22 to bring them in accord with the results secured; but it is possible that the individual feeds require to be multiplied by figures a little higher or lower than 1.22. This can be ascertained only by further comparison of the relative productive energy of the different feeds which enter into the mixture. Application of the correction to the energy coefficients given in Bulletin 372 will be delayed until more information is available regarding the productive energy of the individual feeds.

The productive energy of the mixture here reported gives a basis for estimating the productive energy of chicken feeds more accurately than has previously been the case.

The differences in the corrected productive energy given in Table 17 are not as great between the different experiments as in the preliminary

Table 17. Productive energy of the total feed, the effective organic constituents, the effective digestible nutrients, and of the estimated metabolizable energy.

Series and period	Feed Mix. No.	In total feed, calories per gram				In effective organic constituents, calories per gram	In effective digestible nutrients, calories per gram	Calories metabolizable energy required	
		by corrected energy production coefficients	by periods	by first and last weights	by individual chicks, weights per period			for one calorie of productive energy	in per cent of metabolizable energy
21 days									
50	14	1.80	1.79	1.71	1.80	2.08	2.73	1.50	66.7
51	14	1.80	1.68	1.65	1.71	1.98	2.60	1.58	63.3
55	22	1.82	1.93	1.83	1.93	2.28	2.92	1.40	71.2
56	22	1.82	1.82	1.75	1.82	2.15	2.75	1.49	67.2
58	23	1.83	1.75	1.69	1.76	2.08	2.65	1.55	64.5
60	24	1.77	1.72	1.73	1.70	2.07	2.71	1.52	65.9
Average (6)		1.81	1.78	1.73	1.79	2.11	2.73	1.51	66.5
42 days									
52	18	1.75	1.65	1.95	1.66	1.94	2.56	1.60	62.4
53	18	1.75	1.83	1.65	1.85	2.17	2.86	1.44	69.6
57	23	1.83	1.90	2.24	1.93	2.28	2.90	1.41	70.7
59	24	1.77	1.85	2.03	1.91	2.33	3.04	1.35	74.0
Average (4)		1.77	1.81	1.97	1.84	2.18	2.84	1.45	69.2
84.5 days									
61	25	1.77	1.90	1.58	1.91	2.26	2.87	1.43	70.0
Average of all (11)			1.80	1.80	1.82	2.15	2.78	1.48	67.8
Average of all except 61 (10)		1.79	1.79	1.82	1.81	2.14	2.77	1.48	67.6

values for productive energy given in Table 14. This is probably due partly to the method of calculation, since the algebraic method used for the results in Table 14 may magnify small differences in the data.

The productive energy was likewise calculated for each individual chicken by use of the average maintenance requirements from Table 14, and the data for each chick on full feed in the corresponding experiment. The details are given in Table 18 and the results summarized in Table 19. These are also compared in Table 17. The standard deviation averages .18 calories for chicks 21 days on experiment and .26 for chicks 42 days on experiment. The standard error averages .07 calories for chicks 21 days on experiment and 0.10 for chicks 42 days on experiment.

Table 18. Productive energy of feeds calculated for individual chickens

Laboratory Number	Average weight by periods, gm.	Initial energy content, cal.	Final energy content, cal.	Gain of energy, cal.	Feed eaten, gm.	Feed for maintenance, gm.	Feed above maintenance, gm.	Prod. energy of feed, cal./gm.
Series 50								
35715......	92.0	75.3	288.7	213.5	234.9	110.1	124.8	1.71
35716......	113.4	86.0	375.6	289.5	277.1	135.7	141.4	2.05
35717......	101.4	79.3	290.8	211.5	246.3	121.4	124.9	1.69
35718......	125.2	90.5	401.7	311.2	330.1	149.9	180.3	1.73
Average (4)....	108.0	....	....	256.4	272.1	....	....	1.79
Series 51								
35771......	98.5	84.4	308.3	223.9	263.8	139.6	124.2	1.80
35772......	121.7	98.6	344.7	246.0	351.5	172.5	179.0	1.37
35773......	112.8	88.7	369.9	281.3	316.7	159.9	156.9	1.79
35774......	117.2	102.3	347.9	245.6	298.6	166.1	132.5	1.85
Average (4)....	....	....	....	249.2	307.7	....	....	1.71
Series 52								
36083......	181.3	72.1	722.7	650.6	879.3	533.9	345.5	1.88
36084......	162.6	69.9	655.1	585.1	814.8	478.8	336.0	1.74
36085......	178.7	64.8	712.2	647.4	894.7	526.2	368.5	1.76
36086......	153.1	65.2	515.1	449.9	810.8	450.8	360.0	1.25
Average (4)....	....	....	....	583.3	849.9	....	....	1.66
Series 53								
36262......	202.7	120.3	743.5	623.2	915.6	620.6	295.0	2.11
36264......	198.7	103.9	719.2	615.3	969.6	608.3	361.3	1.70
36265......	200.6	117.8	562.5	444.7	858.0	614.2	243.8	1.82
36266......	192.9	107.5	808.1	700.6	989.6	590.6	399.0	1.76
Average (4)....	....	....	....	595.9	933.2	....	....	1.85
Series 55								
37372......	120.2	80.9	373.4	292.5	336.8	176.9	155.9	1.88
37373......	128.9	73.6	496.1	422.5	381.8	189.7	192.1	2.20
37374......	128.4	77.4	413.8	336.3	374.2	189.0	185.2	1.82
37375......	138.0	83.8	493.0	409.3	385.0	203.1	181.9	2.25
37376......	110.8	67.5	404.0	336.5	337.9	163.1	174.8	1.92
37377......	139.0	79.6	490.0	410.4	411.9	204.6	207.3	1.98
37378......	106.2	61.1	348.1	287.0	319.2	156.3	162.9	1.76
37379......	98.8	59.1	376.7	317.7	322.0	145.4	176.6	1.80
37380......	126.2	78.6	457.9	379.4	398.7	185.8	212.9	1.78
37381......	121.9	81.0	408.0	327.0	351.0	179.4	171.6	1.91
Average (10)....	121.8	....	....	351.9	361.5	....	....	1.93
Series 56								
37471......	106.0	66.4	356.9	290.6	318.0	177.5	140.5	2.07
37472......	104.9	66.2	377.3	311.1	351.7	175.7	176.0	1.77
37473......	130.2	76.0	443.3	367.4	417.5	218.1	199.5	1.84
37474......	121.8	72.9	399.2	326.3	365.0	204.0	161.0	2.03
37475......	114.1	78.0	317.7	239.6	334.4	191.1	143.3	1.67
37476......	121.7	71.1	437.8	366.7	379.7	203.8	175.9	2.08
37477......	102.0	67.0	340.6	273.7	338.9	170.8	168.1	1.63
37478......	105.8	75.2	333.5	258.3	334.3	177.2	157.1	1.64

Table 18. Productive energy of feeds calculated for individual chickens—Continued

Laboratory Number	Average weight by periods, gm.	Initial energy content, cal.	Final energy content, cal.	Gain of energy, cal.	Feed eaten, gm.	Feed for maintenance gm.	Feed above maintenance gm.	Prod. energy of feed, cal./gm.
Series 56—Cont.								
37479......	118.7	73.0	394.9	321.9	392.8	198.8	194.0	1.66
37480......	115.1	62.4	403.8	341.4	376.9	192.8	184.1	1.85
Average (10)....	114.0	....	....	309.7	360.9	....	....	1.82
Series 57								
37620......	227.7	82.6	940.8	858.2	1118.8	749.7	369.1	2.33
37621......	184.1	84.2	850.8	766.6	1026.9	606.2	420.7	1.82
37622......	213.3	87.3	804.2	716.9	1086.2	702.3	383.9	1.87
37623......	215.6	85.7	1037.7	952.1	1250.0	709.9	540.1	1.76
37624......	211.3	91.3	874.8	783.5	1110.6	705.6	405.0	1.93
37625......	195.4	84.7	737.5	652.9	1032.0	643.4	388.6	1.68
37626......	187.5	79.8	813.1	733.3	982.8	617.4	365.4	2.01
37627......	237.4	80.8	1118.7	1037.9	1248.0	781.7	466.3	2.23
37628......	225.3	88.2	771.9	683.7	1168.2	741.8	426.4	1.60
37629......	228.4	84.8	981.9	897.1	1185.1	752.0	433.1	2.07
Average (10)....	212.9	....	....	808.2	1120.9	....	....	1.93
Series 58								
37702......	140.4	108.0	441.7	333.7	430.7	248.7	182.0	1.83
37703......	140.2	113.3	451.0	337.7	428.6	248.4	180.2	1.87
37704......	126.8	103.8	399.0	295.1	371.5	224.7	146.9	2.01
37705......	131.2	111.0	317.4	206.5	344.5	232.4	112.1	1.84
37706......	152.4	109.3	439.9	330.6	477.9	270.0	207.9	1.59
37707......	125.3	103.8	380.3	276.5	406.3	222.0	184.3	1.50
37708......	148.1	113.8	492.0	378.2	466.7	262.4	204.3	1.85
37709......	132.0	102.8	412.3	309.5	387.6	233.9	153.7	2.01
37710......	133.3	106.3	313.8	207.5	365.7	236.2	129.5	1.60
37711......	133.6	110.5	410.2	299.7	434.3	236.7	197.6	1.52
Average (10)....	136.3	....	....	297.5	411.4	....	....	1.76
Series 59								
39372......	235.7	72.1	993.7	921.6	1120.9	777.2	343.7	2.68
39373......	202.7	69.2	771.6	702.5	1034.6	668.4	366.2	1.92
39374......	245.2	76.1	1052.1	976.1	1319.5	808.5	511.0	1.91
39375......	257.9	71.0	991.3	920.4	1417.0	850.4	566.6	1.62
39376......	252.4	74.2	917.6	843.5	1322.7	832.2	490.5	1.72
39377......	271.0	80.4	1135.0	1054.7	1632.3	893.6	738.7	1.43
39378......	227.7	73.0	940.1	867.1	1268.8	750.8	518.0	1.67
39379......	253.5	76.7	1038.6	962.0	1329.6	835.9	493.7	1.95
39380......	253.2	78.9	1101.8	1022.9	1297.2	834.9	462.3	2.21
39381......	221.1	71.8	938.7	866.9	1167.3	729.0	438.3	1.98
Average (10)....	242.0	....	....	913.7	1291.0	....	....	1.91
Series 60								
39534......	109.9	65.5	330.1	264.6	359.7	204.3	155.4	1.70
39535......	81.9	69.6	245.3	175.7	250.7	152.3	98.4	1.78
39536......	97.3	81.0	225.6	144.6	273.2	180.9	92.3	1.57
39537......	102.5	73.5	308.0	234.5	358.8	190.6	168.2	1.39
39538......	98.2	67.4	314.2	246.9	318.1	182.6	135.5	1.82
39539......	91.6	60.5	280.7	220.2	287.2	170.3	116.9	1.88
39540......	128.0	86.0	388.6	302.6	409.3	238.0	171.3	1.77
39541......	89.0	56.4	268.6	212.2	292.1	165.5	126.6	1.68
Average (8).....	99.8	....	....	225.2	318.6	....	....	1.70
Series 61								
39823......	404.2	62.9	1918.2	1855.3	3070.5	2181.8	888.8	2.09
39824......	404.0	65.6	2068.0	2002.4	3068.0	2180.7	887.3	2.26
39825......	368.1	76.9	1614.8	1537.9	2899.0	1986.9	912.1	1.69
39826......	342.5	78.8	1450.1	1371.2	2548.0	1848.7	699.3	1.96
39827......	382.0	75.2	1546.3	1471.1	2940.0	2061.9	878.1	1.68
39828......	446.4	64.8	1829.0	1764.2	3313.0	2409.5	903.5	1.95
39829......	508.6	85.4	2378.3	2292.9	3972.8	2745.3	1227.5	1.87
39830......	343.1	53.5	1603.5	1550.1	2723.3	1852.0	871.4	1.78
Average (8).....	400.5	....	....	1730.6	3066.8	....	....	1.91

There are some wide deviations between the maximum and minimum for the several experiments. Productive energy calculated from experiments on a few animals may thus deviate widely from the average.

Both the standard deviation and the standard error are comparatively low, indicating that the averages are substantially accurate, especially when 6 or more chickens were used in a group.

Examination of the data shows, however, that there are individual chickens for which the productive energy deviates quite widely from the average. The maximum and minimum values are given in Table 19. In Series 55, the productive energy ranges from 1.76 to 2.25, with an average of 1.93. In Series 57 it ranges from 1.60 to 2.33, with an average of 1.93. It seems clear that experiments on a small number of animals might give too high or too low results, and that the results might be misleading. Evidently the individual chickens differ widely in their ability to utilize the energy of feed.

Table 19. Average productive energy of feed calculated from individual chickens.

Series Number	Feed No.	Number of chicks	Productive energy of feed calories per gram			Standard deviation	Standard error
			Average	Maximum	Minimum		
21 days							
50.......	14	4	1.80	2.05	1.69	.17	.08
51.......	14	4	1.71	1.85	1.37	.22	.11
55.......	22	10	1.93	2.25	1.76	.17	.05
56.......	22	10	1.82	2.08	1.63	.18	.06
58.......	23	10	1.76	2.01	1.50	.19	.06
60.......	24	8	1.70	1.88	1.39	.16	.06
Average (6)...	....	8	1.79	2.02	1.56	.18	.07
42 days							
52.......	18	4	1.66	1.88	1.25	.28	.14
53.......	18	4	1.85	2.11	1.70	.18	.09
57.......	23	10	1.93	2.33	1.60	.23	.07
59.......	24	10	1.91	2.68	1.43	.35	.11
Average (4)...	....	7	1.84	2.25	1.50	.26	.10
84.5 days							
61.......	25	8	1.91	2.26	1.68	.20	.07
Average of all (11)......	....	7	1.82	2.13	1.55	.21	.08
Average excluding No. 61	....	....	1.81	....	....	....	....

Similar variations in the maintenance requirements have previously been pointed out. In calculating the productive energy, it has been necessary to use average maintenance values. It is possible that some individual chickens on the full feed had higher or lower maintenance requirements than the average used. This difference in maintenance requirements of the individuals, if it could be allowed for, might increase the differences in the productive energy calculated for the individual chickens, or it might decrease the differences and bring the productive energy values closer together. This is a question which requires further study. It is clear, however, that differences in the animals may result in different utilization of the feed by the individuals, so as to result in different productive energy, and that a sufficient number of animals must be used to equalize the individual differences and thereby secure an accurate average value.

Utilization of the Ration for Maintenance and for Gain

The utilization of the energy of the ration for maintenance and for gain should be of some interest. The quantities of feed calculated as used for maintenance by individual chicks are given in Tables 15 and 18 and are averaged and recalculated for use in Table 20. In the different experiments, the percentages of feed used for maintenance by chicks on limited feed ranges from 60.9 per cent in Experiment 50 to 88.2 in Experiment 58, with an average of 74.2 per cent. The corresponding figures for chicks on full feed range from 47.5 per cent in Experiment 50 to 70.4 in Experiment 61, with an average of 57.9 per cent used for maintenance. The percentage used for gain by chicks on limited feed ranges from 11.8 in Experiment 58 to 39.9 in Experiment 50, with an average of 25.8. The percentage used for gain by chicks on full feed ranges from 29.6 to 52.5, with an average of 42.1. The chicks on experiment 21 days utilized larger proportions of the feed for gain than did those on experiment 42 days.

Table 20. Utilization of the ration for energy of maintenance and of gain by chicks on limited feed and on full feed.

Series and period	Feed No.	Percentage for maintenance		Percentage for gain		Feed eaten per chick per day	
		Limited feed	Full feed	Limited feed	Full feed	Limited feed gm.	Full feed gm.
21 days							
50.....	14	60.9	47.5	39.1	52.5	7.3	13.0
51.....	14	70.3	51.8	29.7	48.2	7.8	14.7
55.....	22	67.7	49.6	32.3	50.4	7.8	17.2
56.....	22	72.4	52.9	27.6	47.1	7.9	17.2
58.....	23	88.2	58.7	11.8	41.3	8.0	19.6
60.....	24	76.1	58.3	23.9	41.7	8.1	15.2
Average (6)	....	72.6	53.1	27.4	46.9	7.8	16.2
42 days							
52.....	18	73.3	58.5	26.7	41.5	11.0	20.2
53.....	18	78.3	65.2	21.7	34.8	11.4	22.2
57.....	23	79.2	62.5	20.8	37.5	10.3	26.7
59.....	24	75.6	61.8	24.4	38.2	11.6	30.7
Average (4)	....	76.6	62.0	23.4	38.0	11.1	25.0
84.5 days							
61.....	25	73.8	70.4	26.2	29.6	18.5	36.3
Average (11)	....	74.2	57.9	25.8	42.1	10.0	21.2

Utilization of Protein

This work was carried out to ascertain the productive energy of the feed, but since data regarding protein are available, they will be briefly discussed. The data give information regarding the utilization of protein by individual animals, but we will discuss the results only on the basis of the averages. Table 21 gives a summary of the average data.

The grams of protein gained divided by the grams of digestible protein fed gives the percentage of the digestible protein stored in the animal, without allowing any protein for maintenance. The average percentages of digestible protein retained are given in Table 22. These averages are remarkably constant.

The retention of digestible protein by the growing chicken is high. The protein stored by the chickens in percentage of the total protein fed is given in Table 22. The average percentage stored by the chickens on the 21 day experiment is 39.3 by those on limited feed and 42.5 by those on full feed, while for those fed 42 days, it is 35.1 for the chickens on limited feed and 38.1 for those on full feed. A little higher percentage is stored by the chickens on full feed than by those on limited feed. The percentage of the digestible protein stored averages 54.7 and 54.9 for 21 days feeding and 51.8 and 50.4 for 42 days feeding.

Table 21. Average protein gained by chicks and eaten in feed.

Series Number	Mix. No.	Protein in chicks			Protein in feed	
		At beginning gm.	At end gm.	Gain gm.	Total gm.	Digestible gm.
Limited feed						
21 days						
50	14	8.25	20.99	12.74	29.95	21.78
51	14	9.29	22.36	13.07	32.17	23.39
55	22	7.83	21.87	14.04	32.00	23.32
56	22	7.28	20.71	13.43	32.20	23.47
58	23	10.67	20.97	10.30	32.36	22.72
60	24	7.38	18.65	11.27	32.06	21.95
Average (6)		8.45	20.93	12.48	31.79	22.77
42 days						
52	18	7.18	39.65	32.47	85.98	59.76
53	18	11.00	40.81	29.81	89.07	61.91
57	23	8.21	35.27	27.06	83.19	58.42
59	24	7.98	41.32	33.34	91.63	62.72
Average (4)		8.59	39.26	30.67	87.47	60.70
84.5 days						
61	25	7.30	107.74	100.44	294.97	193.97
Full feed						
21 days						
50	14	8.37	31.50	23.13	53.47	38.88
51	14	9.46	33.98	24.52	60.46	43.97
55	22	7.84	39.33	31.49	70.24	51.19
56	22	7.20	38.05	30.85	70.12	51.10
58	23	10.72	44.25	33.53	79.44	55.78
60	24	7.30	31.00	23.70	59.40	40.66
Average (6)		8.48	36.35	27.87	65.52	46.93
42 days						
52	18	7.30	70.08	62.78	158.76	110.35
53	18	11.04	71.65	60.61	174.32	121.17
57	23	8.20	91.40	83.20	216.45	151.99
59	24	8.07	104.14	96.07	242.06	165.69
Average (4)		8.65	84.32	75.67	197.90	137.30
84.5 days						
61	25	7.33	199.30	191.97	579.63	381.16

Table 22. Utilization of protein by chicks.

Series Number	Total protein found in gain		Digestible protein found in gain		Protein used for maintenance per day per 100 grams					
					Total		Digestible		Productive	
	Limited feed, per cent	Full feed, per cent	Limited feed, per cent	Full feed, per cent	Limited feed	Full feed	Limited feed	Full feed	Limited feed	Full feed
21 days										
50	42.5	43.3	58.5	59.5	.36	.43	.26	.32	.19	.23
51	40.6	40.6	55.9	55.8	.43	.60	.32	.44	.23	.32
55	43.9	44.8	60.2	61.5	.36	.43	.26	.32	.19	.23
56	41.7	44.0	57.2	60.4	.47	.51	.34	.37	.25	.27
58	31.8	42.2	45.3	60.1	.68	.49	.48	.34	.35	.25
60	35.2	39.9	51.3	58.3	.66	.58	.45	.40	.33	.29
Average (6)	39.3	42.5	54.7	59.3	.49	.51	.35	.37	.26	.27
Average (except 58)	40.8	....	56.6	....	....	....	....	....	....	....
42 days										
52	37.8	39.5	54.3	56.9	.45	.49	.32	.34	.23	.25
53	33.5	34.8	48.2	50.0	.59	.65	.41	.45	.30	.33
57	32.5	38.4	46.3	54.7	.70	.61	.49	.43	.36	.31
59	36.4	39.7	53.2	58.0	.52	.50	.36	.34	.26	.25
Average (4)	35.1	38.1	50.5	54.9	.57	.56	.40	.39	.29	.29
84.5 days										
61	34.1	33.1	51.8	50.4	.48	.54	.32	.36	.23	.26
Average of all (11)	37.3	40.0	52.9	56.9	.52	.53	.36	.37	.27	.27

The feed nitrogen retained by rats is given at an average of 17.9 to 18.8 per cent in one set of experiments (9) and 20.3 to 24.1 in another (4). The percentage of total protein stored by growing chickens (39 to 42) is much higher than the percentage stored by rats (17.9 to 24.1). However, in experiments with growing rats, Forbes et al., (10) secured somewhat higher figures for the retention of nitrogen, ranging from 23 to 41 per cent, but still lower than for the chickens.

The productive value of the digestible protein was calculated by an algebraic method similar to that used for productive energy. The values for the productive value of the protein for the individual tests varied widely, being from .55 to .89. The average for the 6 experiments of 21 days was 0.71 and for the 4 experiments of 42 days was 0.73. These two averages have a high measure of agreement. The value of 0.73 was used to calculate the protein maintenance requirements and the productive protein value of digestible protein, in a similar way to that used for productive energy. The equation used is $M = \frac{FX - G}{W}$, in which M is the maintenance requirement per gram of animal, for the entire period; F is the grams of digestible protein eaten; X is the productive coefficient for protein (0.73 here used); G is the grams of protein gained by the animal; and W is the average weight (by periods). The maintenance requirement given in the table is for a day per 100 grams, which is 100 M divided by 21 days or 42 days. The protein used for maintenance per day per 100 grams of chicken is given in terms of productive protein, of digestible protein (productive protein divided by .73), and of total protein (digestible protein divided by coefficient of digestibility). There are considerable differences between the maintenance values calculated from the different experiments. The average values were 0.51 gm total protein per day per 100 grams for the chickens on full feed 21 days, 0.49 for those on limited feed, and 0.56 gm for the chickens on experiment 42 days full feed and 0.57 for those on limited feed. These values agree quite closely.

Considerable work has been done on the biological values of proteins, although generally with percentages of protein lower than those used in practical feeding. As summarized by Boas Fixsen (7), the biological value of the proteins of cereals and seeds in a ration containing over 10% protein ranges from 57 to 71, legumes from 38 to 72, tankage at 74, and coconut at 58. This is an expression in percentages of the body nitrogen stored divided by the food nitrogen absorbed minus the metabolic nitrogen of feces and urine. The maximum of biological values is near the average of 73 for productive protein obtained in the work here reported, while the average of the biological values cited would be appreciably below this figure of 73. It appears probable that the protein of cereals may be utilized by animals to a larger extent than has been previously assumed from consideration of the biological values.

SUMMARY

Eleven experiments involving 256 chicks were made for the purpose of ascertaining the productive energy of a basal mixture of feed, in order to secure fundamental values which could be used as the basis of a system of productive energies of poultry feeds.

Representative chicks were analyzed at the beginning of the test. One lot of chicks was fed individually all the mixture they would eat; the other lot was fed individually about half this quantity. All chickens were analyzed for protein and fat at the end of the test. Digestion experiments were made on the feed mixtures used with chicks of similar age. The gains in energy of the chicks, calculated from the protein and fat content of the chicks and the quantity of feed consumed, together with the length of the feeding period, gave data from which to calculate the maintenance requirements of the chicks and the productive energy of the feed.

Individual chickens differ in their capacity to grow and to utilize feed. Appreciable variations were found in the weights and composition of the chicks fed the same feed for the same period of time, especially in the fat, which might vary from 2.53 to 6.13 per cent for chicks on limited feed, or from 6.60 to 11.17 per cent for chicks on full feed as between individual chickens in the same experiment. The energy content of the chicks did not vary as much as the fat. The difference between the maximum and minimum calorie content is only 10% of the average with some groups, and less than 15% with many of them.

The maintenance requirements of the chicks and the productive energy of the feed were calculated in two ways, first on the assumption that the maintenance requirements vary according to the surface area, and second that they vary according to the weight. The maintenance requirements and the productive energy were lower when calculated on a surface basis than when calculated on the weight basis. The productive energy calculated on the surface basis was appreciably lower for the 42 days experiments than for the 21 days experiments, but when calculated on the weight basis, the results were almost the same for both these periods of experiment. Higher values for productive energy were secured when maintenance requirements were calculated on the weight basis than when calculated on the surface basis. These higher values are much more nearly in accord with the results secured by other workers by means of respiration experiments on chicks fed corn and rats fed mixed feeds; and the weights of the feed required for maintenance are not out of line with work reported by others.

The use of the average weights by periods gives more concordant results than the use of the mean of the initial and final weights of the chicks. The use of the average data gave practically the same results as the longer method of calculating from the data of individual chickens and averaging this data.

The productive energy of the mixture was on an average 22% higher than the productive energy calculated from the factors previously given

in Texas Bulletin 372. This value can be used to correct productive energy values of chicken feeds previously reported as soon as sufficient data on the relative productive energy of different kinds of feeds are available.

The productive energy required for maintenance as calculated from these experiments is lower than the requirements of energy for basal metabolism of chickens, as found by other workers. However, the quantity of feed required for maintenance is higher per day per kilogram of weight than the quantities given by other workers for larger chickens.

Appreciable differences in maintenance requirements, with no corresponding change in productive energy, were found between different experiments on practically the same feed mixtures. These differences in maintenance requirements are ascribed to differences in environmental conditions affecting the chicks.

While the basal metabolism of chickens as reported by other workers is more nearly in proportion to the calculated surface area than to the weight, the maintenance requirements, as found in the experiments here reported, are more nearly in proportion to the weight than to the surface area.

The maintenance requirements as found, average per day per kilogram, are 74.8 grams of total feed, 63.3 gm of effective organic constituents, 48.7 gm of effective digestible nutrients, 134 calories of productive energy, and 200 calories of metabolizable energy. The effective organic constituents are the sum of the protein, the ether extract X 2.25, and the nitrogen-free extract, as the ash, water, and crude fiber are not considered to furnish energy to chickens. The effective digestible nutrients are the sum of the digestible protein, digestible ether extract X 2.25, and digestible nitrogen-free extract.

The average of the standard deviations for the productive energy of the feed mixtures is 0.21 on 1.82 calories of productive energy per gram, or about 11 per cent, while the average of the standard errors is 0.08, or about 5 per cent. If only a few chickens were used, the results secured might deviate appreciably from the actual value. The average maximum is 2.13 and the average minimum is 1.55 calories per gram, the difference being 0.58, or 27 per cent of the maximum.

The productive energy averaged 1.79 calories per gram of the feed used. The productive energy of the effective organic constituents was 2.14 calories per gram, of the effective digestible nutrients 2.77 calories per gram; and 67.6 per cent of the calculated metabolizable energy, over maintenance, was used for productive purposes.

The average maintenance requirement for chickens 28 to 50 days old is 132 calories of productive energy per kilogram live weight per day. The average of the standard deviations is 8.9, or about 7%; and the average of the standard error is 3.5, or about 3%. There is less variation in the average maintenance within the experiments than in the productive energy.

On an average 25.8 per cent of the limited ration was used for gain in weight and 42.1 per cent of the full ration. The remainder was used for maintenance.

As an average of all the 11 experiments, 40.0% of the total protein was stored in the chicks on full feed and 37.3% in those on limited feed. Of the digestible protein, 56.9% was stored in chicks on full feed and 52.9 in those on limited feed.

If the productive value of the protein is calculated by a method similar to that used for productive energy, differences are found between the individual experiments, but the productive value of the digestible protein averages 0.71 for the 21 days period and 0.73 for 42 days. The productive value of the protein so calculated is higher than the usual biological value received for similar foods. It appears possible that the biological value of the protein of cereals is higher than it has been considered from previous work.

Using the value 0.73 of the digestible protein for productive protein, the average productive protein required for maintenance was 0.27 gm per 100 gm a day for chicks on limited feed and on full feed. The maintenance requirements for digestible protein averaged 0.37 gm per day per 100 gm of chicks and the maintenance requirements for total protein averaged 0.53 per day per 100 gm.

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